

Landscape change and age ratios for mule deer (*Odocoileus hemionus*) herd units in Wyoming, 1980-2019



Photograph: Mule deer doe with two fawns in montane grassland. Photograph by Teagan Hayes.

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Contents

Project introduction.....	5
Statewide Results	7
Changes in mule deer recruitment	7
Land use and habitat composition.....	10
Weather and climate	10
Energy development	11
Wildfire	13
Habitat treatments	14
Mechanical treatments, rangeland.....	15
Chemical (Spike) treatments, rangeland	16
Pinedale – Jackson regions	17
Winter-use areas.....	17
Recruitment.....	18
Changes in landscape variables.....	19
Trends by herd unit	19
Land use	20
Average winter temperature (December-March of previous year).....	21
Summer precipitation (May-August of the previous year)	22
Cumulative drought	23
Changes in energy development density.....	24
Green River region.....	26
Winter use areas	26
Recruitment.....	27
Changes in landscape variables.....	28
Trends by herd unit	28
Land use	29
Average winter temperature (December-March of previous year).....	30
Summer precipitation (May-August of the previous year)	31
Cumulative drought	32
Changes in energy development density.....	33
Cody region.....	35

Winter-use areas.....	35
Recruitment.....	36
Changes in landscape variables.....	37
Trends by herd unit	37
Land use	38
Average winter temperature (December-March of previous year)	39
Summer precipitation (May-August of the previous year)	40
Cumulative drought	41
Changes in energy development density.....	42
Lander region	44
Winter use areas	44
Recruitment.....	45
Changes in landscape variables.....	46
Trends by herd unit	46
Land use	47
Average winter temperature (December-March of previous year)	48
Summer precipitation (May-August of the previous year)	49
Cumulative drought	50
Changes in energy development density.....	51
Sheridan region	53
Winter-use areas.....	53
Recruitment.....	54
Changes in landscape variables.....	55
Trends by herd unit	55
Land use	56
Average winter temperature (December-March of previous year)	57
Summer precipitation (May-August of the previous year)	58
Cumulative drought	59
Changes in energy development density.....	60
Casper region	62
Winter-use areas.....	62
Recruitment.....	63
Changes in landscape variables.....	64

Trends by herd unit	64
Land use	65
Average winter temperature (December-March of previous year)	66
Summer precipitation (May-August of the previous year)	67
Cumulative drought	68
Changes in oil/gas density	69
Laramie region	71
Winter-use areas	71
Recruitment	72
Changes in landscape variables	73
Trends by herd unit	73
Land use	74
Average winter temperature (December-March of previous year)	75
Summer precipitation (May-August of the previous year)	76
Cumulative drought	77
Changes in oil/gas density	78
References	80
Acknowledgements	81
Appendix	83

Landscape change and age ratios for mule deer (*Odocoileus hemionus*) herd units in Wyoming, 1980-2019

Project introduction

Sagebrush ecosystems and wildlife that depend on them are under pressure from development, changing climate, and natural and human-caused disturbance (Bergman et al. 2015). This project is part of a long-term, multi-taxa study that seeks to inform land management decisions. This work was supported by the Wyoming Landscape Conservation Initiative (WLCI), a collaboration between the U.S. Geological Survey (USGS), Wyoming Game and Fish Department (WGFD), Bureau of Land Management (BLM), the University of Wyoming, and several other entities involved in land management in southwestern Wyoming. Using several phases of research, this project aims to assess the effects of disturbances and habitat treatments on wildlife, especially how changing conditions might influence long-term population management. In Wyoming, mule deer are of particular concern following population declines in the state and the western region (Mule Deer Working Group 2018). Wyoming Game and Fish Department and other agencies have invested considerable resources to identify ungulate movement corridors and wintering areas, as part of the Wyoming Migration Initiative. In this report, on this phase of the project, we focused on how changes in sagebrush ecosystems influence age ratios of mule deer. We assessed age ratio relationships with disturbance and habitat treatments on winter-use areas to understand potential effects of future development, management, and conservation in sagebrush communities across the state.

Objectives for Phase 1 of this project were to:

- 1) assess changes in recruitment over time,
- 2) quantify the amount of disturbance and cumulative habitat change within areas of concentrated winter-use for each mule deer herd unit, and
- 3) evaluate the degree to which environmental conditions and human activities in winter-use areas influence recruitment to provide context for management action.

An implicit goal of this work was to extend knowledge previously developed from localized and mechanistic research across the landscape to enable interpretation and applications by managers and planners. Collaborators representing the USGS, BLM, WGFD, and the University of Wyoming participated throughout this project. In collaboration with these entities, findings are detailed in Hayes et al. (2026), “Integrating climate and anthropogenic dynamics can inform multifaceted management for declining mule deer populations” in the journal *Ecological Applications*.

This report provides a short summary of published results (Hayes et al. 2026) and greater detail on findings to facilitate understanding changes in mule deer winter-use areas. We also provide herd-specific graphs and information for herd units within seven WGFD regions (WGFD, State of Wyoming 2020): Pinedale and Jackson, Green River, Cody, Lander, Sheridan, Casper, and Laramie (Fig. 1).

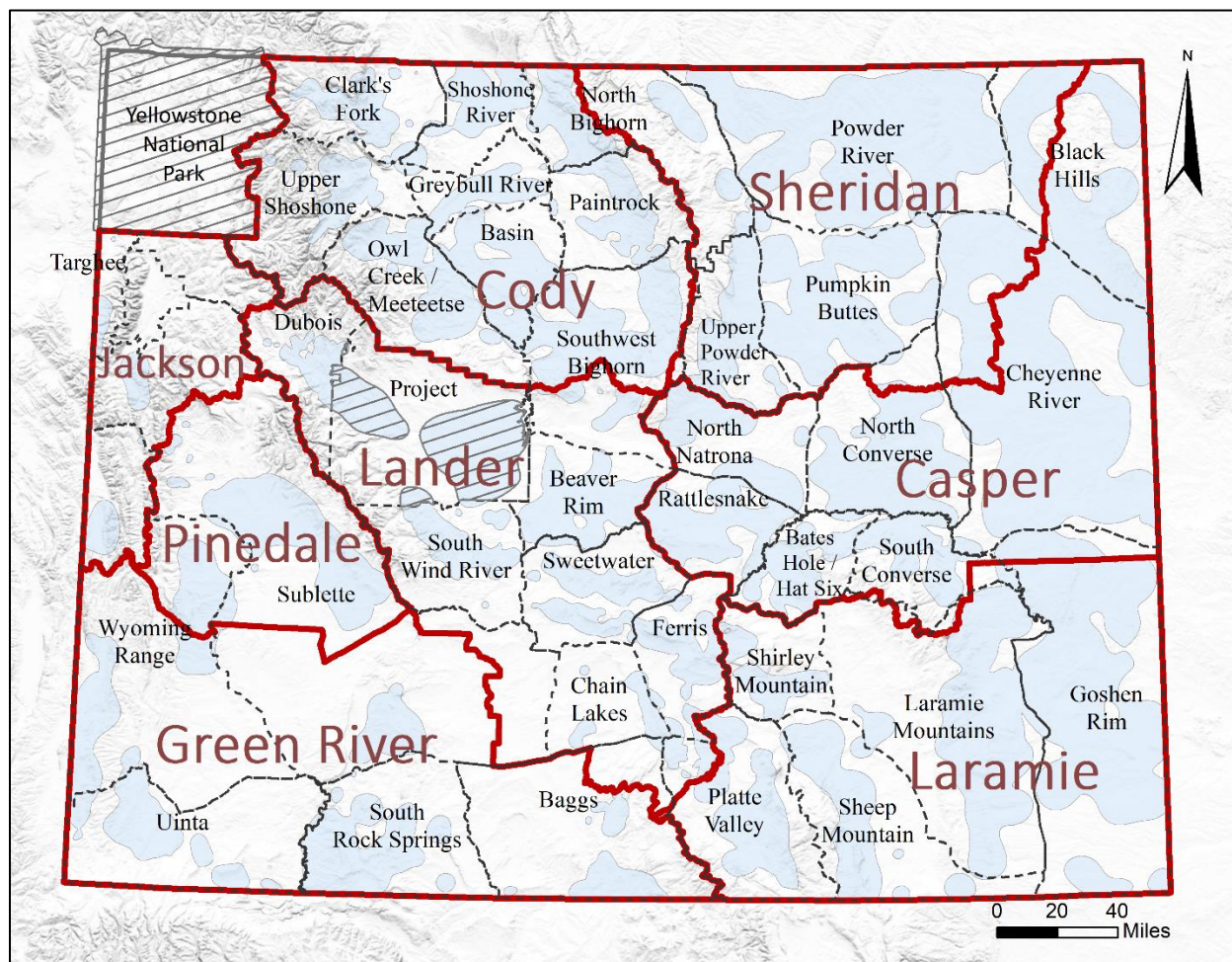


Fig. 1. Map of mule deer winter-use contours, shown with blue polygons, in Wyoming, USA. Winter-use areas are truncated by herd unit boundaries, shown as dotted lines (serif font). Wyoming Game and Fish Department (WGFD) regions are shown with red lines (larger, red sans serif font). Analysis excludes Yellowstone National Park and the Project herd areas (hatched lines), which do not have consistent long-term age-ratio data. Hillshade data credit: Esri, Maxar, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap, and the GIS user community.

Statewide Results

Winter use by mule deer is largely contained within herd management units defined by WGFD, whereas many herds do not remain in the same unit during the summer. Because deer use is more concentrated in winter, changes to winter range can affect a greater number of individuals and are more likely to influence survival and demographic trends at the population level (Parker et al. 1984, Hobbs 1989). Therefore, we focused analysis on winter-use areas across the entire state.

To describe environmental conditions for mule deer in winter, we delineated winter-use areas across the entire state. We used WGFD's 'wildlife observations system' database (Wyoming Game and Fish Department 2021), which included biologist counts from annual aerial and ground surveys and opportunistic observations. Using winter (December-March) data only from all years of the study, which included surveys classifying the ages of observed deer, we created one 85% kernel density estimate (KDE) for every herd unit to represent core areas with consistent use by mule deer. We also used global positioning system (GPS) location data from 25 mule deer research projects across multiple herd units to create a second set of 85% KDEs (Kauffman et al. 2020). For herd units with both GPS and survey location data, we merged KDE polygons.

Changes in mule deer recruitment

To examine changes in mule deer populations, we used data on mule deer age ratios recorded annually by WGFD from 1980 - 2019. Age ratios (the number of juvenile deer per 100 adult females) provide an index of local mule deer populations and offer higher sensitivity to changes in recruitment (survival rate of young) and population growth rate than other metrics (Harris et al. 2010).

Recruitment varied substantially across 36 herd units (**Fig. 2**). The mean age ratio across all herd units from 1985-2019 was 66.4 fawns/100 adult females (SE = 0.36), with mean ratios ranging from 15 to 126 in different herd units. Across all herd units, in 1985 the modeled mean ratio was 70.7 (SE = 0.6), and in 2019, it was 60.5 (SE = 0.7). Throughout the 35-year study, age ratios declined by an average of 0.2 ± 0.03 (SE) fawns/year.

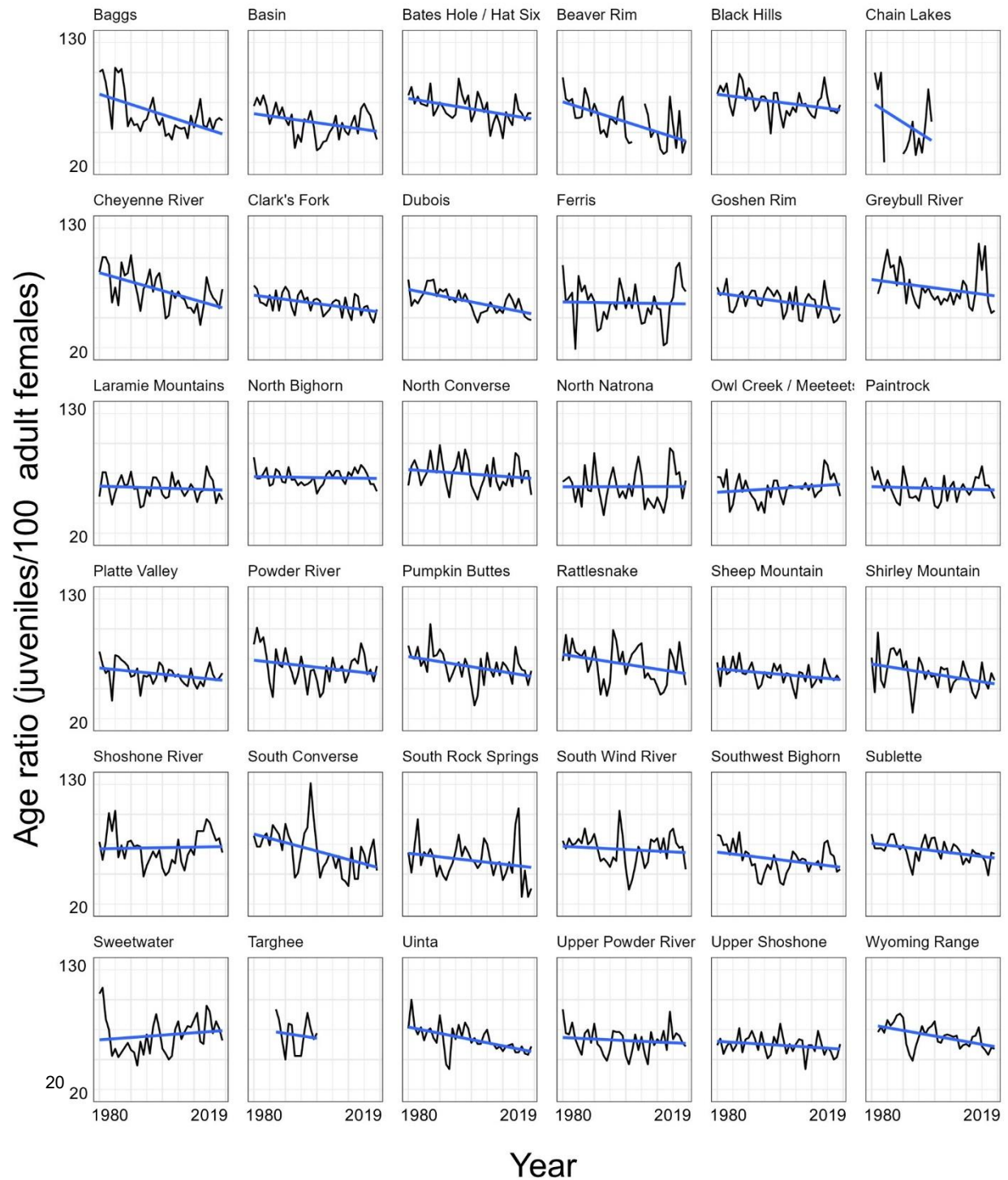


Fig. 2. Mule deer age ratios (the proportion of juveniles/100 adult females) by herd units in Wyoming, USA from 1980-2019, showing the linear trend (blue line) on the same scale for all herd units.

Average rates of change varied greatly among herd units, ranging from -0.85 fawns/100 adult females per year in Baggs to 0.20 in Sweetwater. Twenty herd units had statistically significant ($p \leq 0.05$) declines, although 32 herd units showed declining trends over time. One herd unit exhibited almost no change ($< \pm 0.01$ fawns/100 adult females/year) and 3 herd units exhibited slightly increasing (though not statistically significant) trends. Average rates of change varied from -2.0 to 0.20 fawns/100 adult females/year. As described in full detail in [Hayes et al. \(2026\)](#), to connect mule deer recruitment to landscape conditions, we summarized changes in winter-use areas from long-term datasets representing 6 categories of landscape variables: forage availability, habitat composition, predation, winter severity, energy development, and disturbances from wildfire and habitat treatments. We used linear mixed models with random intercepts for herd unit to investigate the relationship between recruitment and each category. The overall best-supported model included all model categories except for predation. We used this model to predict statewide effects of the proportion of agriculture and shrubland, summer precipitation, mean winter temperature, and cumulative drought on mule deer age ratios (**Fig. 3**).

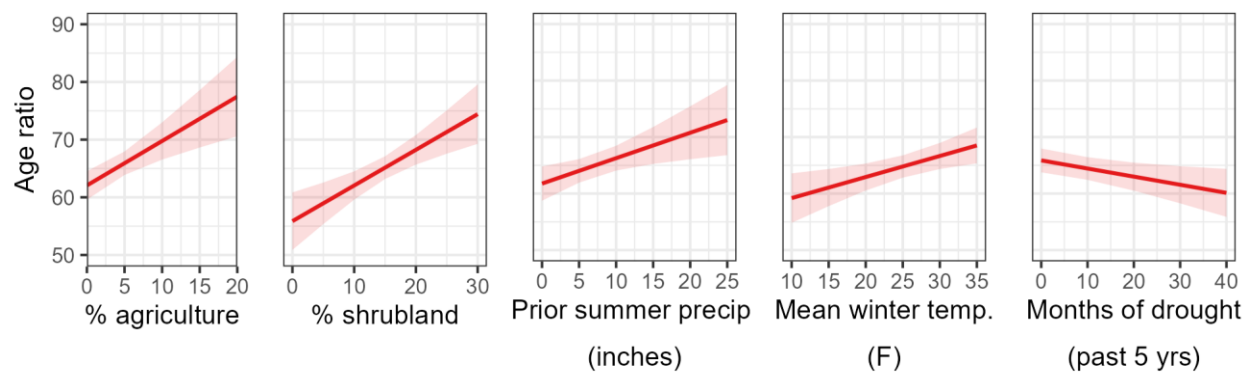


Fig. 3. Predicted statewide effects in Wyoming, USA across deer winter-use areas of the proportion of agriculture and shrubland, summer precipitation (May-August) in the year before counts, mean winter temperature (December-March), and cumulative drought on mule deer age ratios from 1980-2019.

Below, for each of the categories for which we found influences on age ratios, we describe general patterns for the variables within categories predicted to have effects on age ratios in our final model.

Land use and habitat composition

Arid rangeland (grassland, sagebrush, and shrubland) dominates winter-use areas for all herd units except Targhee. Conifer forest occurred in all but 2 winter use areas (Chain Lakes and Greybull River), but the proportion varied greatly among herd units (0.7% - 44.9%). Aspen forest occurred in 15 of 36 winter-use areas, and where present, comprised less than 5% of winter-use areas in all but the Targhee herd unit.

Agriculture and shrubland had the strongest predicted effects on age ratios of any variables tested.

Agriculture (defined as cropland, hay land, and food production excluding rangeland) comprised < 2% of the winter-use area for 13 herd units. The proportion of agriculture in winter-use areas varied significantly across herd units and over time. Between 1985 and 2019, winter-use areas in 25 herd units contained $\geq 2\%$ agriculture and 2 herd units contained $\geq 20\%$, Shoshone River and Greybull River. On average, 26 of 36 winter-use areas declined in the proportion of agriculture between 1985 and 2019. The mean proportion of winter-use areas comprised of agriculture fell from 4.2% to 3.8% for all herd units combined during that time. Although declines in agriculture area were relatively small, the large predicted effect of agriculture on age-ratios translated into decreases of 0.42 juveniles/100 does for each 1 percent decrease in agriculture.

The proportion of shrubland (bitterbrush shrub steppe, desert shrub, greasewood fans and flats, mesic upland shrub, saltbush fans and flats, and xeric upland shrub) in winter-use areas varied across herd units, ranging from 4.4% to 27.5% during the study period but did not have a strongly directional change over time. 35 herd units contained $\geq 10\%$ shrubland and 12 herd units contained $\geq 20\%$ in winter-use areas.

Weather and climate

Cumulative drought, summer precipitation and winter temperatures emerged as predictors of age ratios in this category (Hayes et al. 2026). Cumulative drought, calculated as the number of months of severe drought during the previous 5 years (60 months), ranged from 0.0 to 38.4 months. Across the state, drought was distributed unequally throughout the state but increased significantly in 23 herd units between 1985 and 2019. Temporal change in cumulative drought over time accounted for a greater amount of total variation than spatial variation. In years with large cumulative drought, variability among herd units was high. Conversely, in years with low cumulative drought, variability was low. Herd units with more cumulative drought were more variable over time. Across the state, drought variability tended to decrease as the amount of drought decreased, showing some herd units were buffered from cumulative drought (**Fig. 4**).

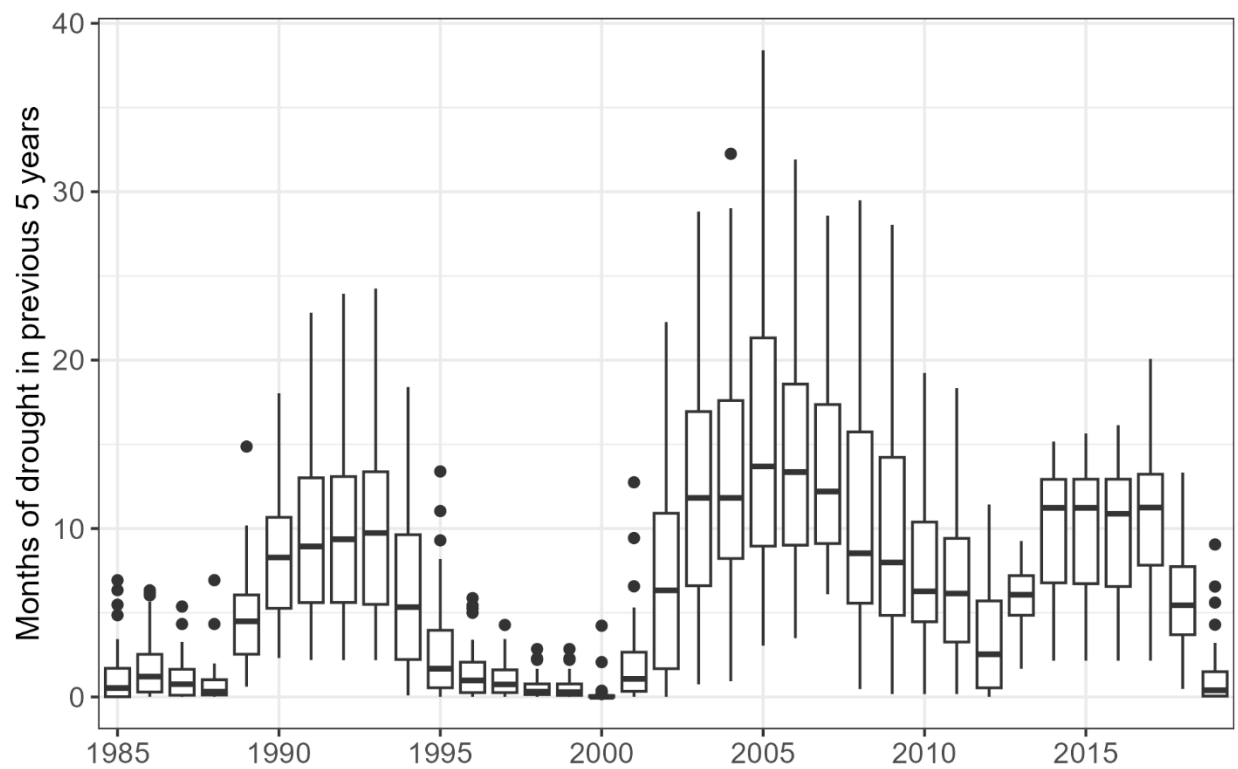


Fig. 4. Changes in cumulative drought (months of severe drought during the previous 5 years) averaged across all mule deer winter-use areas within herd units in Wyoming, 1985-2019. Boxes show 25th and 75th percentiles and the median line, whiskers extend to the largest values within 1.5 * IQR (interquartile range), and dots show outliers. Figure originally published as Creative Commons CC BY in [Hayes et al. \(2026\)](#).

Although cumulative drought increased during the study period, summer precipitation did not significantly change over time and temporal variation was minimal. Summer precipitation for a single herd unit-year ranged from 36 mm to 517 mm and varied between herd units. Statewide, the driest summers on average occurred in 2013 (84.5 mm), 1995 (101 mm), and 1989 (113 mm). Overall, winter temperatures increased over time (32 herd units), with significant increases in 7 herd units. Mean winter temperatures varied greatly across years and herd units, although patterns were generally consistent between herd units.

Energy development

The presence and density of energy development in mule deer winter-use areas changed significantly during the study period. Oil and gas development occurred in all winter-use areas except the Targhee herd unit. In all other herd units in 2019, well density in winter-use areas ranged from 0.002 wells/km² in North Bighorn herd unit to 3.0 wells/km² in Baggs herd unit. Well density varied

substantially among deer herd units, particularly in the southwest and northeast parts of the state (Baggs, Sublette, Pumpkin Buttes, and Powder River herd units). Oil and gas development began in the early 1900s, but began rising sharply in 1998, concurrent with the first wind energy production. The density of oil and gas wells changed over time, increasing 60.3% during the study period, from 27,175 in 1985 to 43,554 in 2019, but with a peak of 60,358 wells in 2010.

The first wind turbines in Wyoming were constructed in 1998 in one herd unit (Sheep Mountain). New wind development increased after 1998 but slowed in 2010, then continued to increase more rapidly in 2019 (**Fig. 5**). and there were 1,122 turbines in 7 herd units by 2019. Where present, the density of wind turbines ranged from 0.002 turbines/km² (1 turbine, Chain Lakes herd unit) to 0.12 turbines/km² (310 turbines, Sheep Mountain herd unit) in 2019. Multiple wind development sites are currently under construction in the Baggs and Platte Valley herd units.

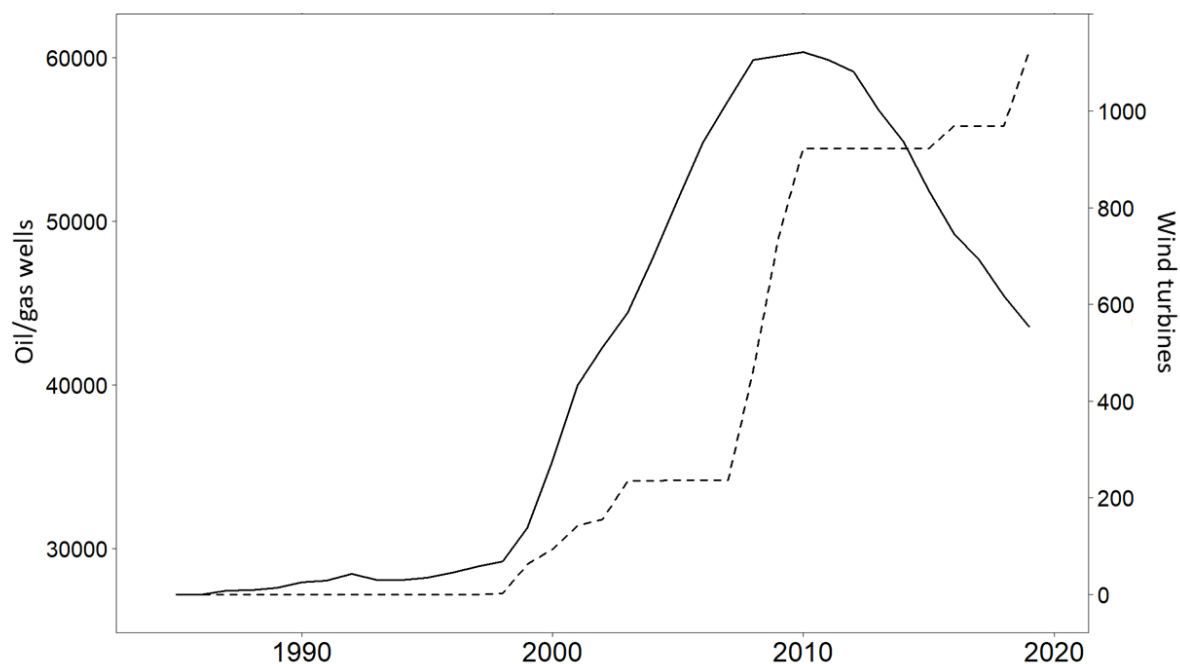


Fig. 5. Total number of operational oil/gas wells (left axis, solid line) and wind turbines (right axis, dashed line) over time, on different scales, in mule deer winter-use areas in Wyoming, USA from 1980-2019. Figure originally published as Creative Commons CC BY in [Hayes et al. \(2026\)](#).

Wildfire

Wildfire was widespread across herd units, with wildfire present during at least one year in all winter-use areas. Coverage of wildfire in winter-use areas varied among herd units ($F = 18.55$, $p < 0.001$), and the proportion burned increased in nearly all herd units (32) between 1980-2019, with significant increases in 11 herd units. Wildfire in winter-use areas was most abundant in 2001, 1997, and 2014.

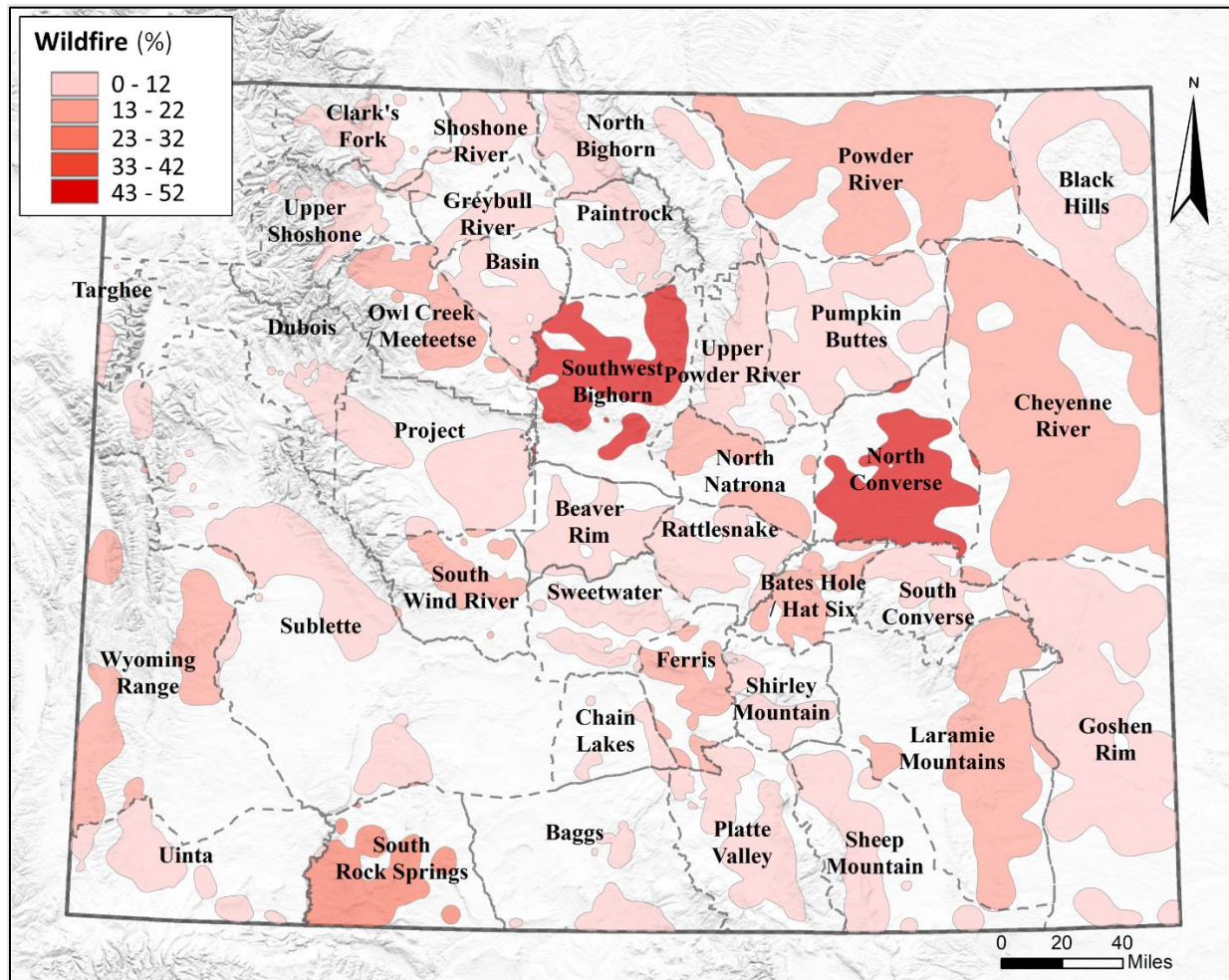


Fig. 6. Relative proportion of mule deer winter-use areas affected by wildfire in Wyoming, USA between 1980-2019. Darker colors represent a greater percentage of fire within a winter-use area relative to other herd units and do not show the geographic location or the area of fire boundaries. Hillshade data credit: Esri, Maxar, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap, and the GIS user community.

Habitat treatments

Habitat treatment data are gathered by agencies that conduct treatments. Each agency records information in different ways, using different definitions, details and context of treatments, and variable reporting on treatment success. We combined treatment data from 5 sources: WGFD (Wyoming Game and Fish Department 2020), Land Treatment Digital Library (LTDL; Pilliod et al. 2019), Density Disturbance Calculation Tool (DDCT; Wyoming Geographic Information Science Center 2016), Vegetation Management Action Portal (Bureau of Land Management 2021), and the Vegetation Treatment Geodatabase (Bureau of Land Management 2020). We divided habitat disturbance and restoration into multiple categories representing 3 treatment types (prescribed burn, chemical, and mechanical) plus a wildfire category (Appendix, Table S1).

Rangeland (including grassland and sagebrush) comprised the largest vegetation cover of winter-use areas in all herd units except Targhee. Most herd units (30) had mechanical treatments of rangeland/sage applied after 1991. Treatments in this dataset were concentrated in 3 herd units (24.4% in Greybull River, 16.3% in the Wyoming Range, and 12.8% in South Wind River) and varied substantially over time. Chemical treatments to rangeland/sage in winter-use areas began in 1994. Application varied considerably over time and was restricted to 12 herd units. Prescribed fire treatments in rangeland/sage were applied in 27 of 36 herd units. Prescribed burning began before 1980, and its application peaked in 1999 before declining. Habitat treatments to aspen landcover were applied in 12 of 15 herd units containing aspen forest. In aspen forests, application of prescribed fire treatments increased and then declined between 1992-2019, whereas mechanical treatments began later (2000), but generally increased. Prescribed burns in conifer forest began before 1980, peaked in 2004, and then declined. Most forest prescribed burns (85.7%) occurred in 5 herd units.

Mechanical treatments, rangeland

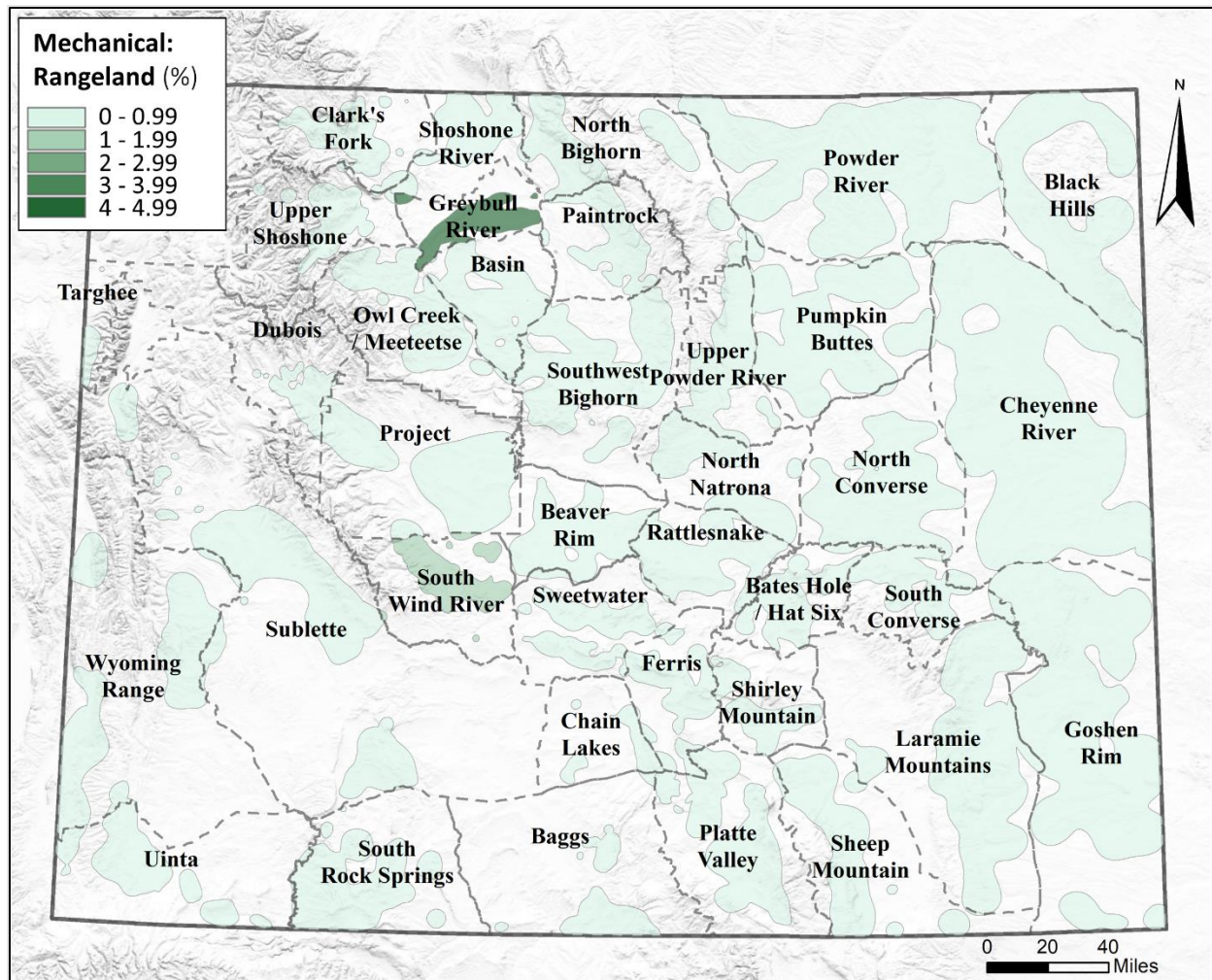


Fig. 7. Total percentage of mule deer winter-use area in Wyoming, USA that received mechanical treatments in rangeland between 1980-2019 in our dataset. Hillshade data credit: Esri, Maxar, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap, and the GIS user community.

Chemical (Spike) treatments, rangeland

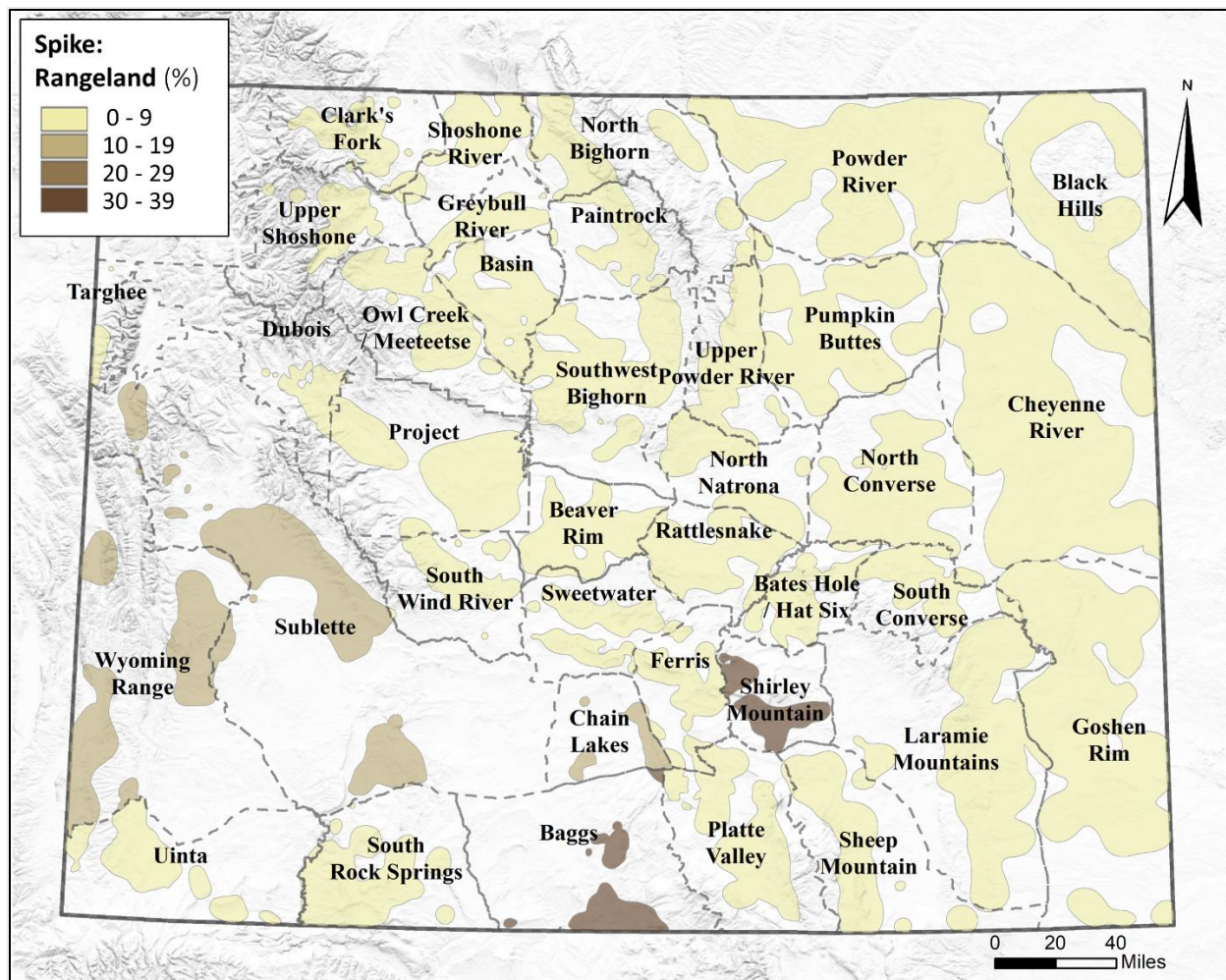


Fig. 8. Total percentage of mule deer winter-use area in Wyoming, USA that received Spike chemical treatments in rangeland between 1980-2019 in our dataset.

Pinedale – Jackson regions

Winter-use areas

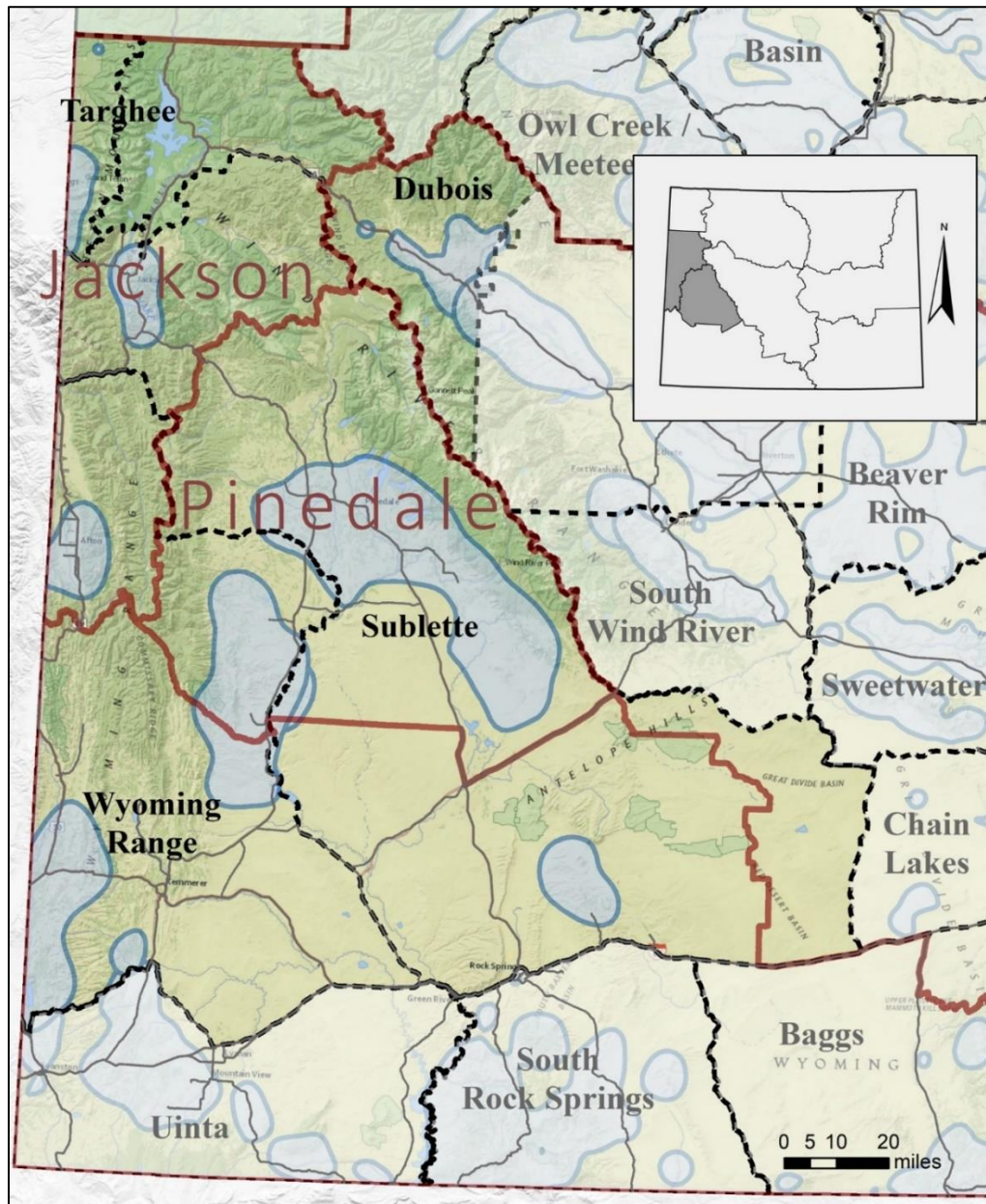


Fig. 9. Mule deer herd units in Wyoming, USA delineated by dashed black lines (bold text), regions delineated by solid red lines (larger, sans serif text), and winter-use areas (blue polygons) within Pinedale and Jackson Wyoming Game and Fish Department (WGFD) regions (WGFD, State of Wyoming 2020). Inset map shows region location in relation to the state of Wyoming. National Geographic World Map basemap credit: Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Recruitment

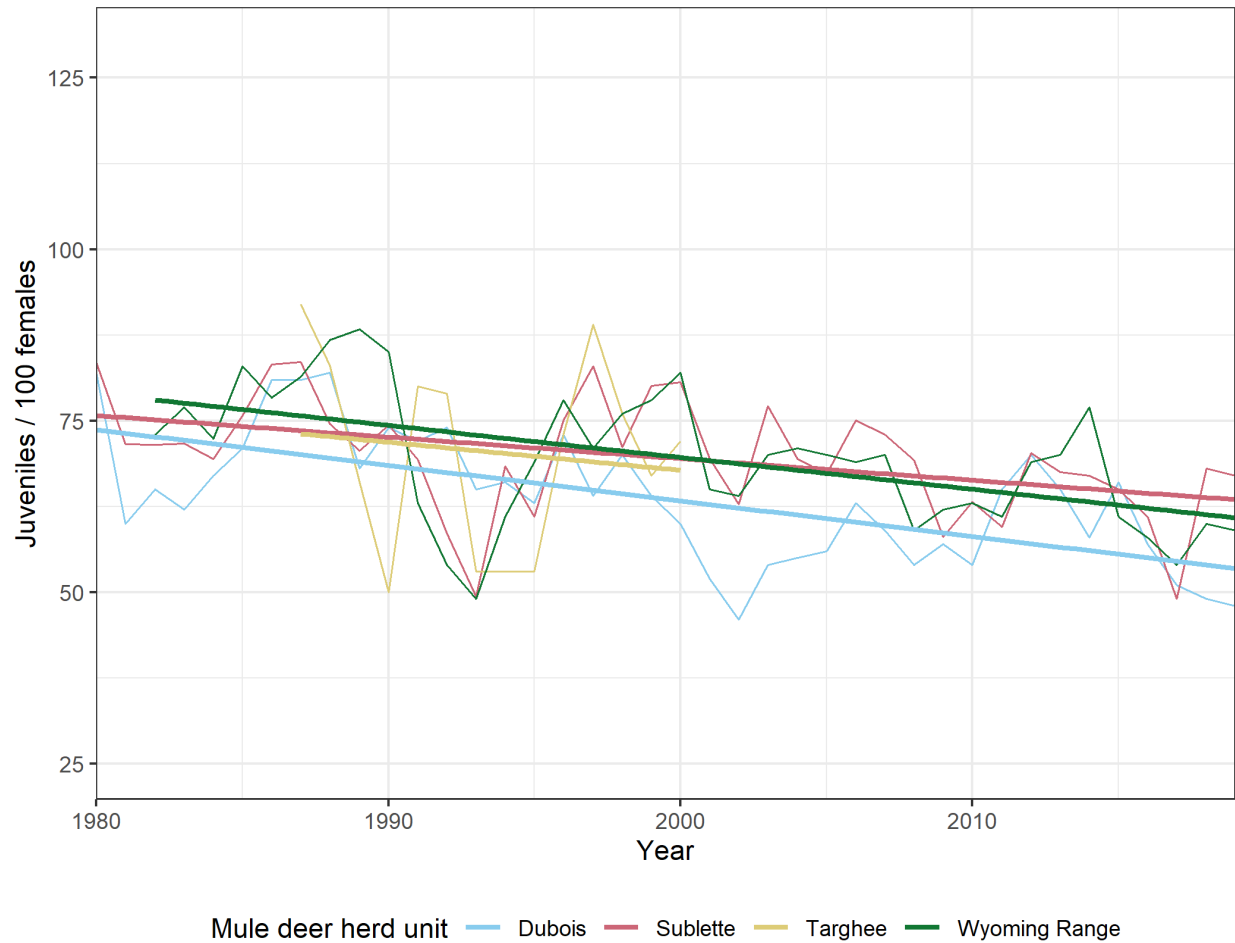


Fig. 10. Mule deer age ratios (proportion of juveniles/100 adult females) by herd unit in Pinedale and Jackson Wyoming Game and Fish Department (WGFD) regions, 1980–2019. Trend line for herd unit in Targhee has limited age ratio data (14 years available: 1987–2000).

Changes in landscape variables

Trends by herd unit

In the Pinedale-Jackson regions, winter temperatures, drought, and oil and gas wells had large changes in some or all herd units (Table 1).

Table 1. Trends from linear regression for landscape variables in mule deer herd units from 1980-2019 in Wyoming, USA. Values represent relative effects and are scaled so variables can be directly compared. Bolded values represent trends that are statistically significant ($p \leq 0.05$). Significant trends are also summarized as: *increase* + (>0), *large increase* ++ (≥ 0.01), *decrease* - (≥ -0.01), or *large decrease* -- (≤ -0.01). Ag = agriculture.

	Dubois	Sublette	Targhee	Wyoming Range
Ag	-0.014 --	0.005	-0.063 --	-0.017 --
Drought	0.143	0.211 ++	-0.033	0.104
Oil/gas wells	<-0.001 -	0.042 ++	0.000	0.015 ++
Shrubland	0.018	0.067	-0.015	0.037
Summer precipitation	-0.462	-0.526	-1.050	0.046
Wind	NA	NA	NA	NA
Winter temperatures	0.071 ++	0.047 ++	0.074 ++	0.064 ++

Land use

Although land use proportion was relatively stable over time, the amount of shrubland and agriculture varied across herd units. Shrubland includes bitterbrush shrub steppe, desert shrub, greasewood fans and flats, mesic upland shrub, saltbush fans and flats, and xeric upland shrub. Agriculture is defined as cropland, hay land, and food production excluding rangeland.

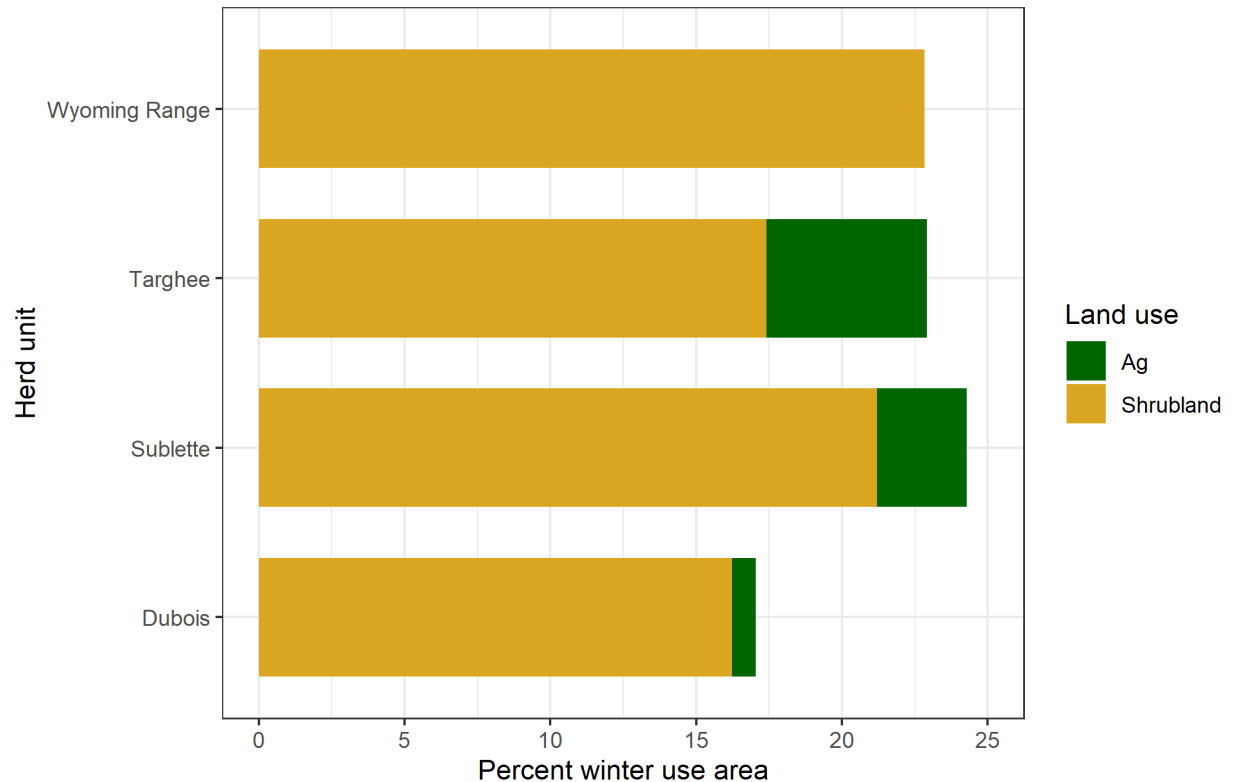


Fig. 11. Mean proportion of agriculture and shrubland in winter-use areas for 1985-2019 by mule deer herd unit in Pinedale and Jackson Wyoming Game and Fish Department (WGFD) regions, Wyoming, USA.

Average winter temperature (December-March of previous year)

Mean winter temperatures (December-March before counts) across herd units varied over time. Mean temperatures in winter-use areas differed by herd units, but fluctuations over time tracked closely between herd units.

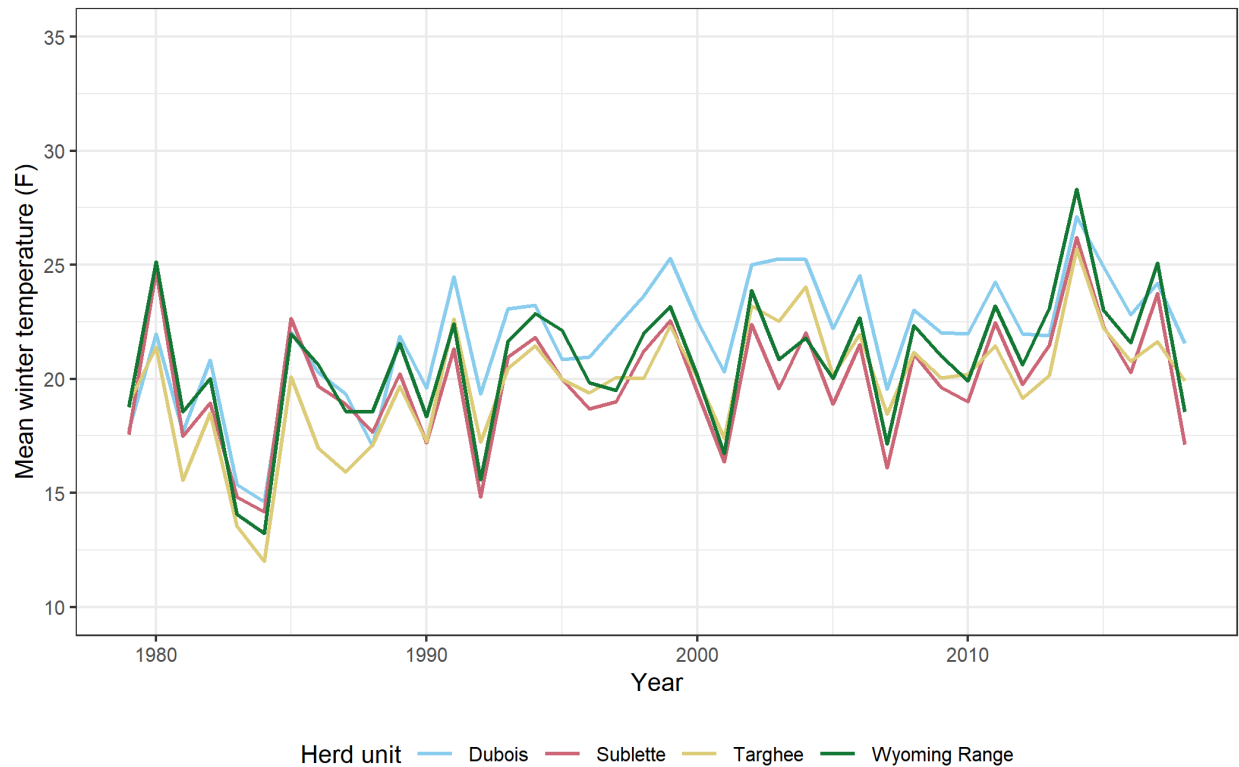


Fig. 12. Mean temperature (°F) in winter-use areas of mule deer herd units in Pinedale and Jackson Wyoming Game and Fish Department (WGFD) regions, 1980–2019, Wyoming, USA.

Summer precipitation (May-August of the previous year)

Precipitation during May-August of the year before counts varied considerably across herd units over time. Targhee herd unit had consistently more precipitation than other herd units, but fluctuations in summer rainfall over time mostly tracked between herd units in the region.

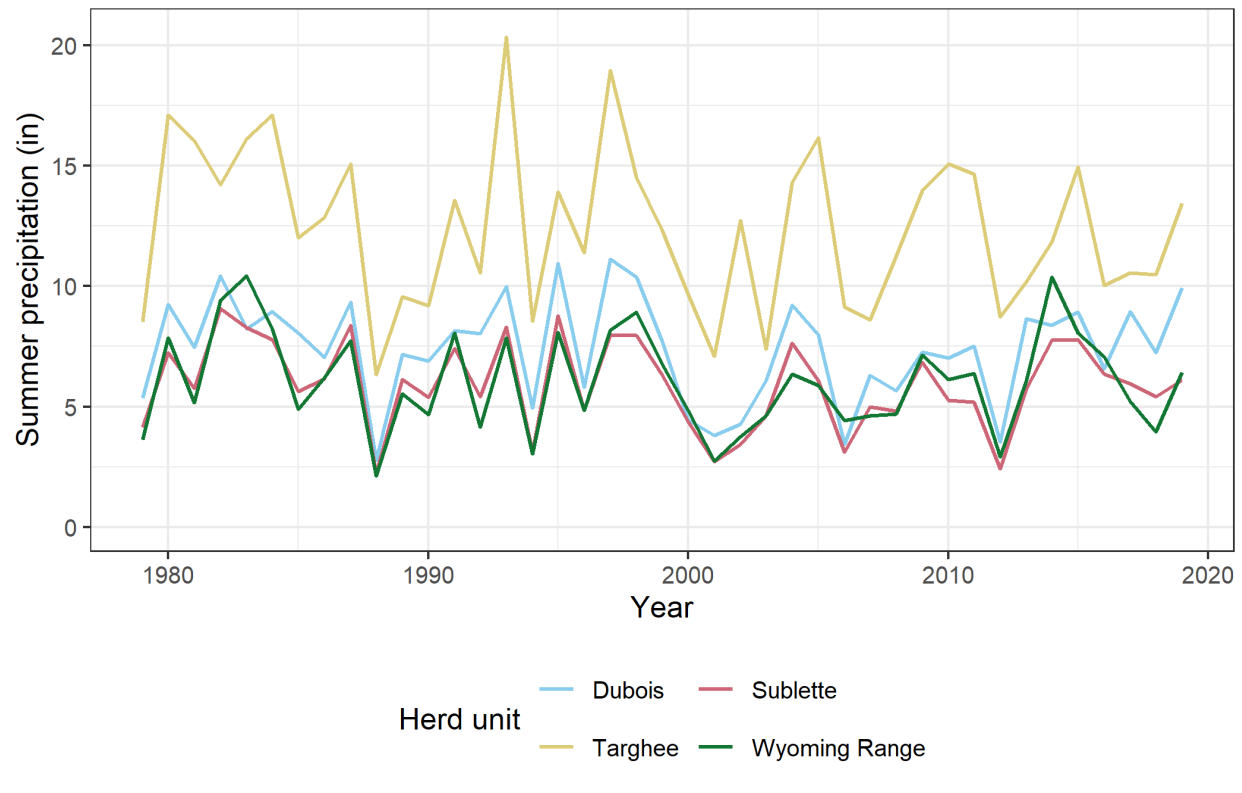


Fig. 13. Mean precipitation (inches) during the previous May-August in winter-use areas of mule deer herd units in Pinedale and Jackson Wyoming Game and Fish Department (WGFD) regions, 1980–2019, Wyoming, USA.

Cumulative drought

Cumulative drought (the number of months with severe drought) across herd units varied over time but patterns of drought occurrence were similar between herd units. Targhee was the exception, missing most of the drought months between 2001 and 2019.

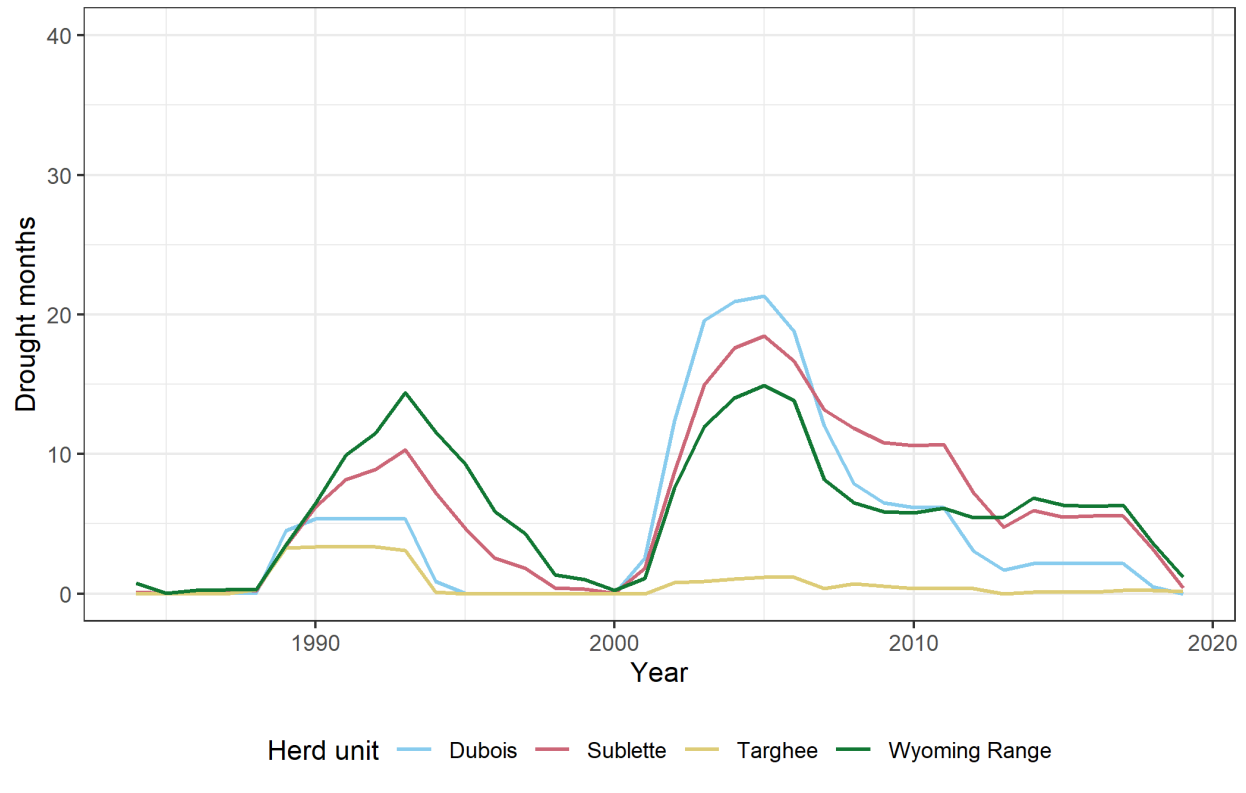


Fig. 14. Cumulative drought (months of severe drought during the previous 5 years) in mule deer winter-use areas within herd units in Pinedale and Jackson Wyoming Game and Fish Department (WGFD) regions, 1985-2019, Wyoming, USA.

Changes in energy development density

Oil and gas development increased in the Sublette herd unit, with a greater rate of development starting around 2005. Development in the Wyoming Range herd unit was at a higher density in 1980, but density increased more slowly and with a slight tapering off after 2008. No development occurred in Dubois and Targhee herd units.

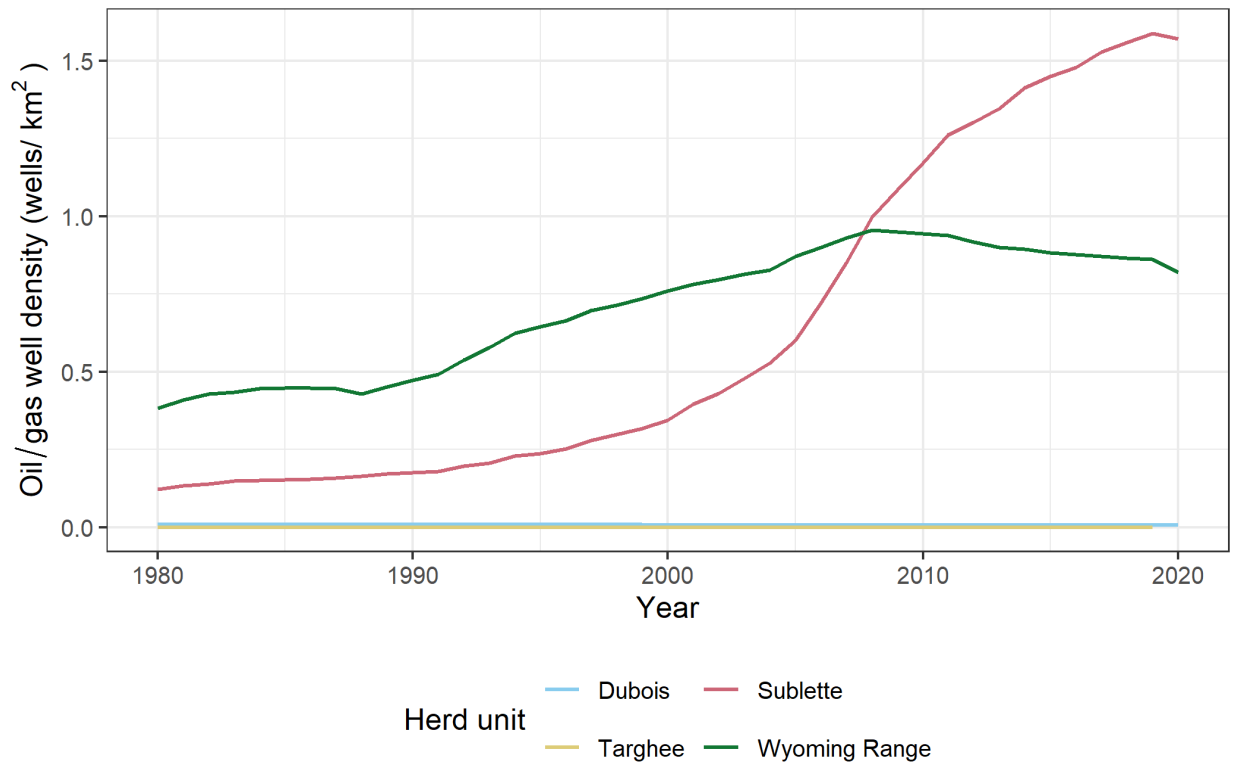


Fig. 15. Operational oil/gas well density (wells/km²) over time by mule deer herd unit in Wyoming, USA.

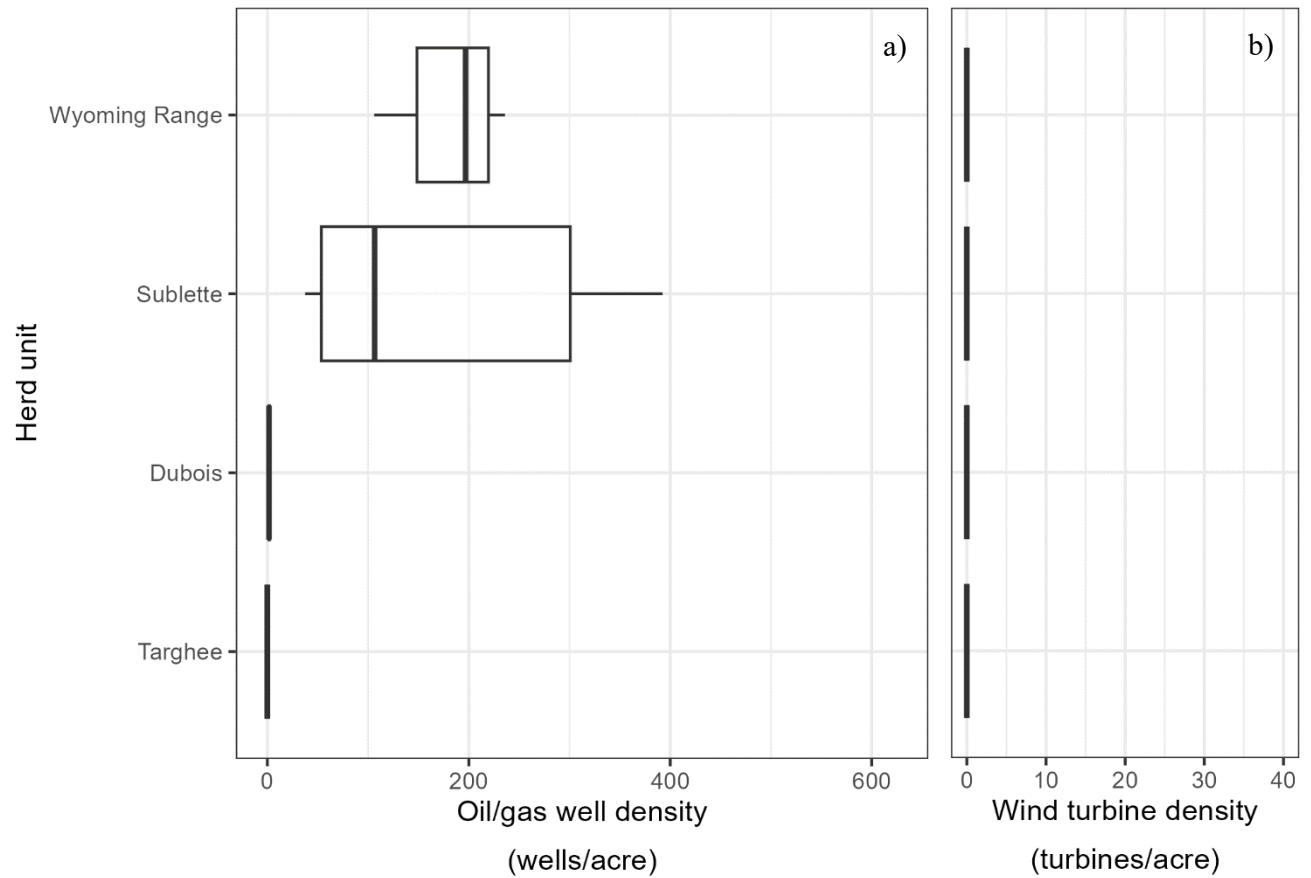


Fig. 16. Spatial variability in density of (a) oil/gas wells and (b) wind turbines in mule deer winter-use areas in Pinedale and Jackson Wyoming Game and Fish Department (WGFD) regions, 1985-2019, Wyoming, USA. Boxplots are on different scales and both show first quartile, median, and third quartile of data, with whiskers extending to the largest value within 1.5 * IQR (interquartile range) and outliers plotted as individual points.

Green River region

Winter-use areas

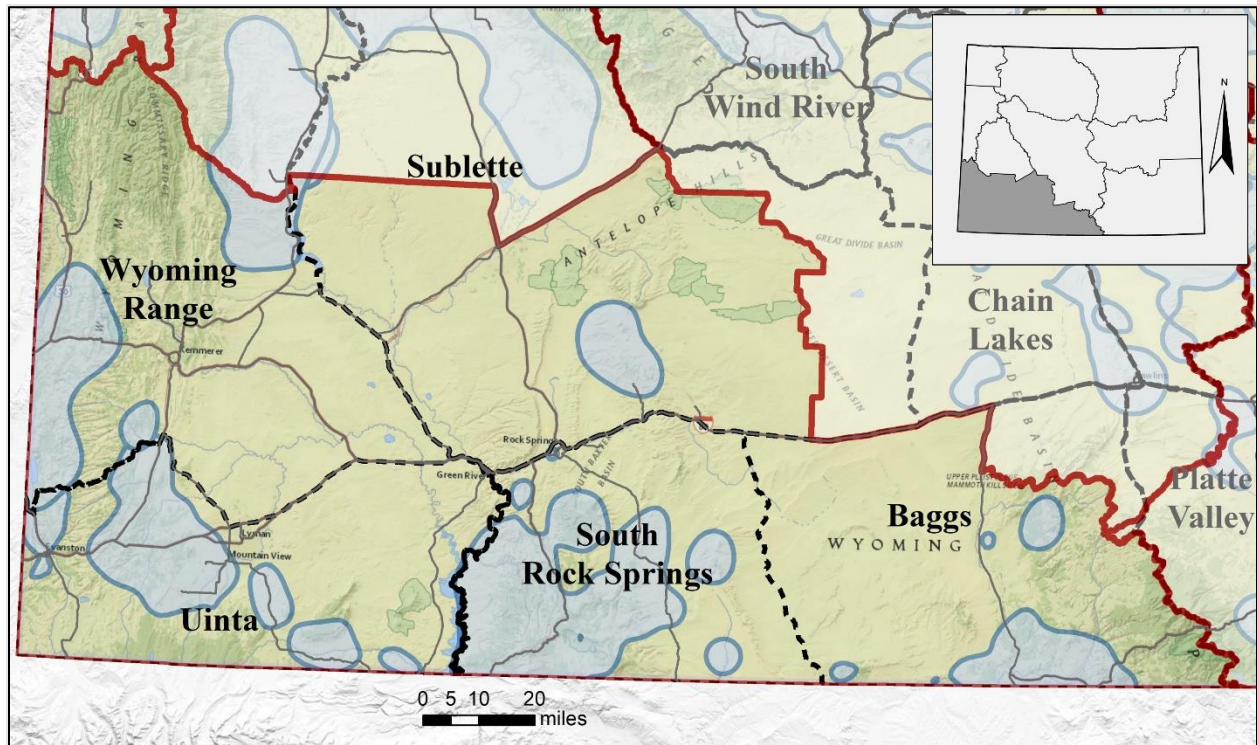


Fig. 17. Mule deer herd units delineated by dashed black lines (bold text), regions delineated by solid red lines and winter-use areas (blue polygons) within Green River region of Wyoming Game and Fish Department (WGFD, State of Wyoming 2020). Roads shown as grey lines. Inset map shows region location in relation to the state. National Geographic World Map basemap credit: Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Recruitment

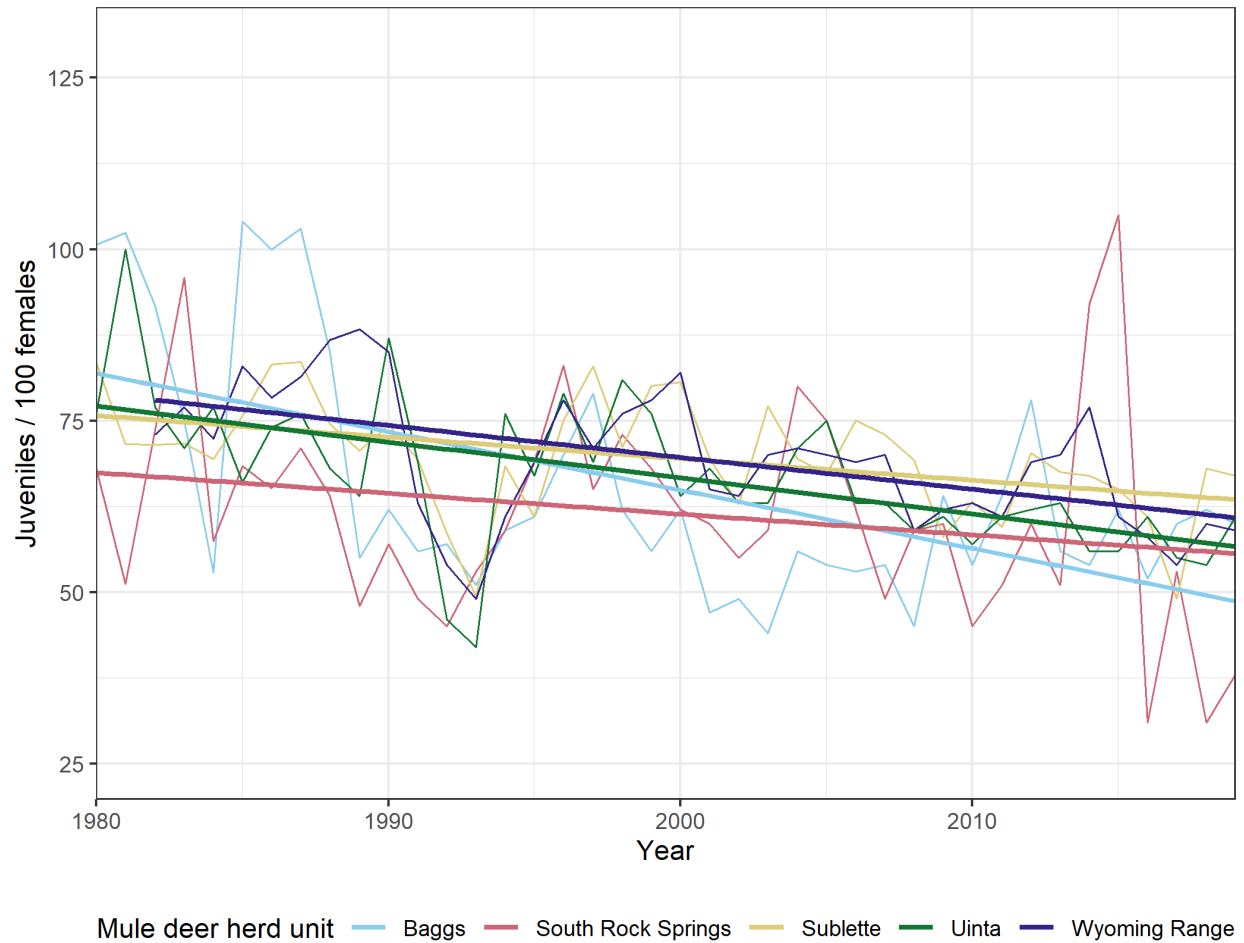


Fig. 18. Mule deer age ratios (proportion of juveniles/100 adult females) by herd unit in Green River Wyoming Game and Fish Department (WGFD) region, 1980–2019, Wyoming, USA.

Changes in landscape variables

Trends by herd unit

In the Green River region, agriculture, drought, winter temperatures, and oil and gas wells had large changes in many herd units (Table 2).

Table 2. Trends from linear regression for landscape variables in mule deer herd units from 1980-2019, Wyoming, USA. Values represent relative effects and are scaled so variables can be directly compared. Bolded values represent trends that are statistically significant ($p \leq 0.05$). Significant trends are also summarized as: *increase* + (>0), *large increase* ++ (≥ 0.01), *decrease* - (≥ -0.01), or *large decrease* -- (≤ -0.01). Ag = agriculture.

	Baggs	South Rock Springs	Sublette	Uinta	Wyoming Range
Ag	0.018 ++	-0.0002 +	0.005	0.026 ++	-0.017 --
Drought	0.227 ++	0.415 ++	0.211 ++	-0.007	0.104
Oil/gas wells	0.083 ++	0.002 +	0.042 ++	-0.00004	0.015 ++
Shrubland	0.011	-0.072 --	0.067	-0.00006	0.037
Summer precipitation	-0.665	0.333	-0.526	-0.049	0.046
Wind	NA	NA	NA	0.003 +	NA
Winter temperatures	0.057 ++	0.053 ++	0.047 ++	0.040	0.064 ++

Land use

Although land use proportion was relatively stable over time, the amount of shrubland and agriculture varied across herd units. Shrubland includes bitterbrush shrub steppe, desert shrub, greasewood fans and flats, mesic upland shrub, saltbush fans and flats, and xeric upland shrub. Agriculture is defined as cropland, hay land, and food production excluding rangeland.

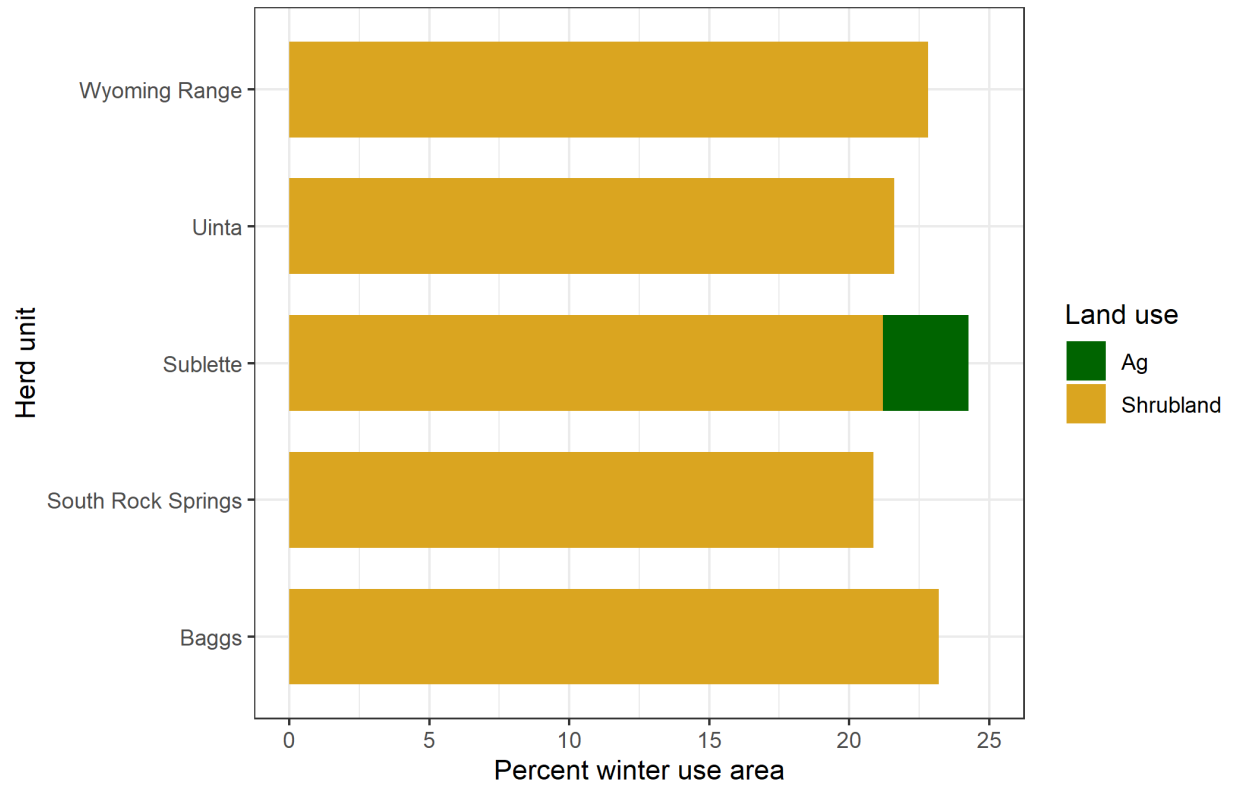


Fig. 19. Mean proportion of agriculture and shrubland in winter-use areas for 1985-2019 by mule deer herd unit in Green River Wyoming Game and Fish Department (WGFD) region, Wyoming, USA.

Average winter temperature (December-March of previous year)

Mean winter temperatures across herd units varied over time. The mean temperature differed by herd units, but patterns tracked closely over time between herd units.

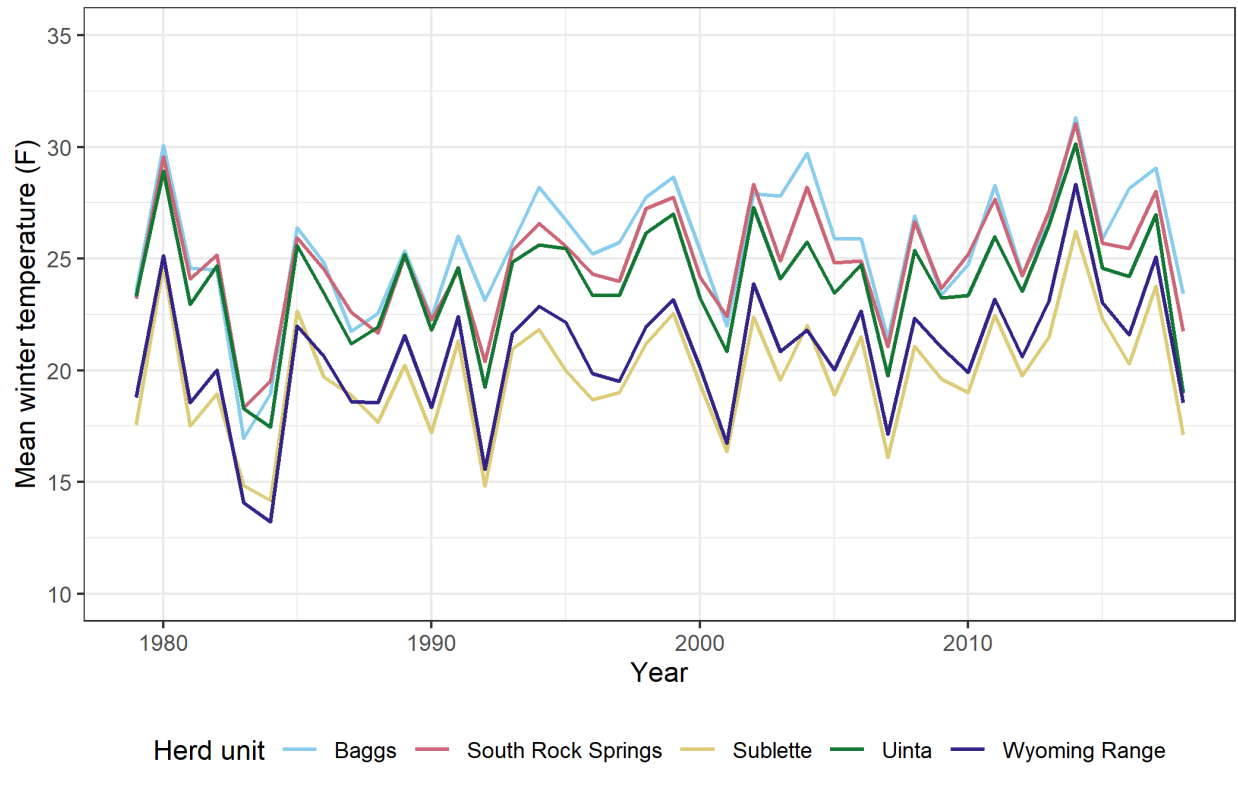


Fig. 20. Mean temperature (°F) in winter-use areas of mule deer herd units in Green River Wyoming Game and Fish Department (WGFD)region, 1980–2019, Wyoming, USA.

Summer precipitation (May-August of the previous year)

Precipitation during May-August of the year before counts varied over time but was similar between herd units.

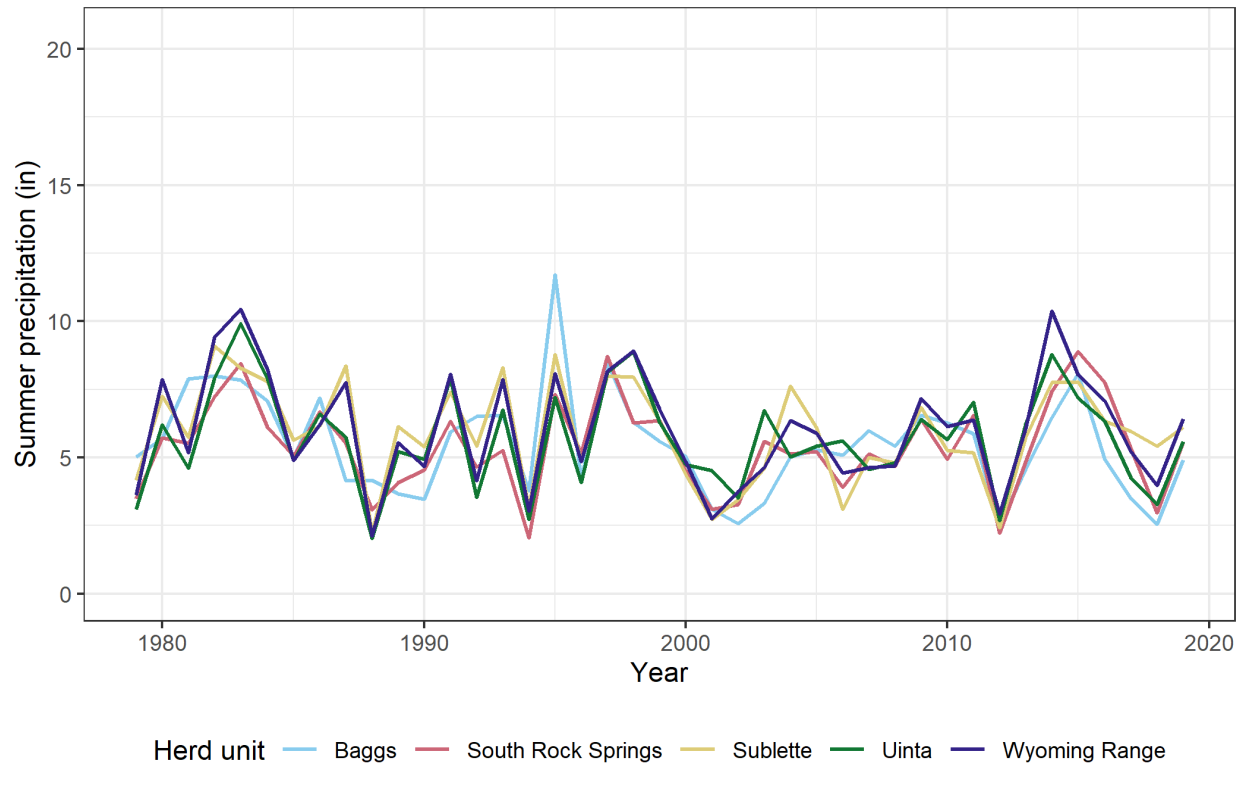


Fig. 21. Mean precipitation (inches) during the previous May-August in winter-use areas of mule deer herd units in Green River Wyoming Game and Fish Department (WGFD) region, 1980–2019, Wyoming, USA.

Cumulative drought

Cumulative drought (the number of months with severe drought) across herd units varied over time with some herd units experiencing more months of severe drought when drought occurred and other herd units sometimes experiencing fewer months of drought (e.g., Baggs in 2008-2012, Sublette and Wyoming Range in 2014-2018).

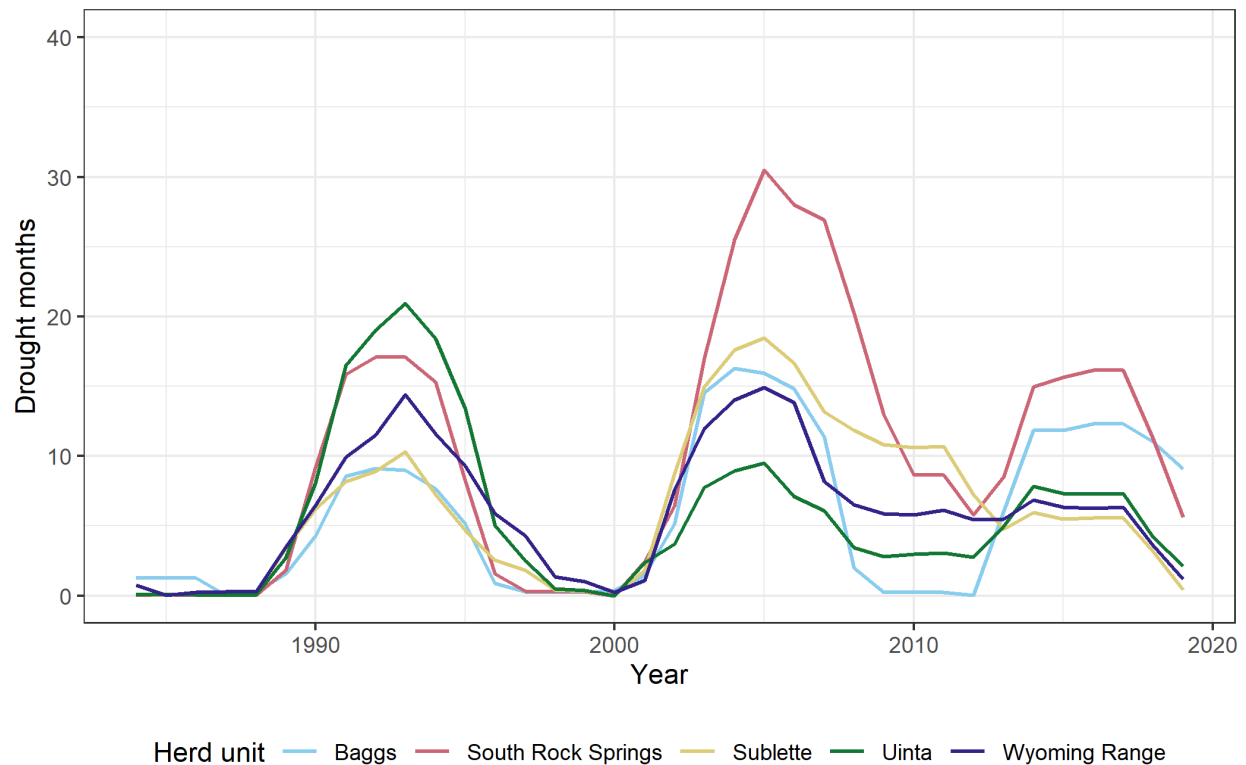


Fig. 22. Cumulative drought (months of severe drought during the previous 5 years) in mule deer winter-use areas within herd units in Green River Wyoming Game and Fish Department (WGFD) region, 1985-2019, Wyoming, USA.

Changes in energy development density

Oil and gas development increased in the Baggs herd unit, with a greater rate of development starting around 2005. Development in the Wyoming Range herd unit was at a higher density in 1980 than other units in this region, but density increased more slowly and declined slightly after 2008. No development occurred in Dubois and Targhee herd units.

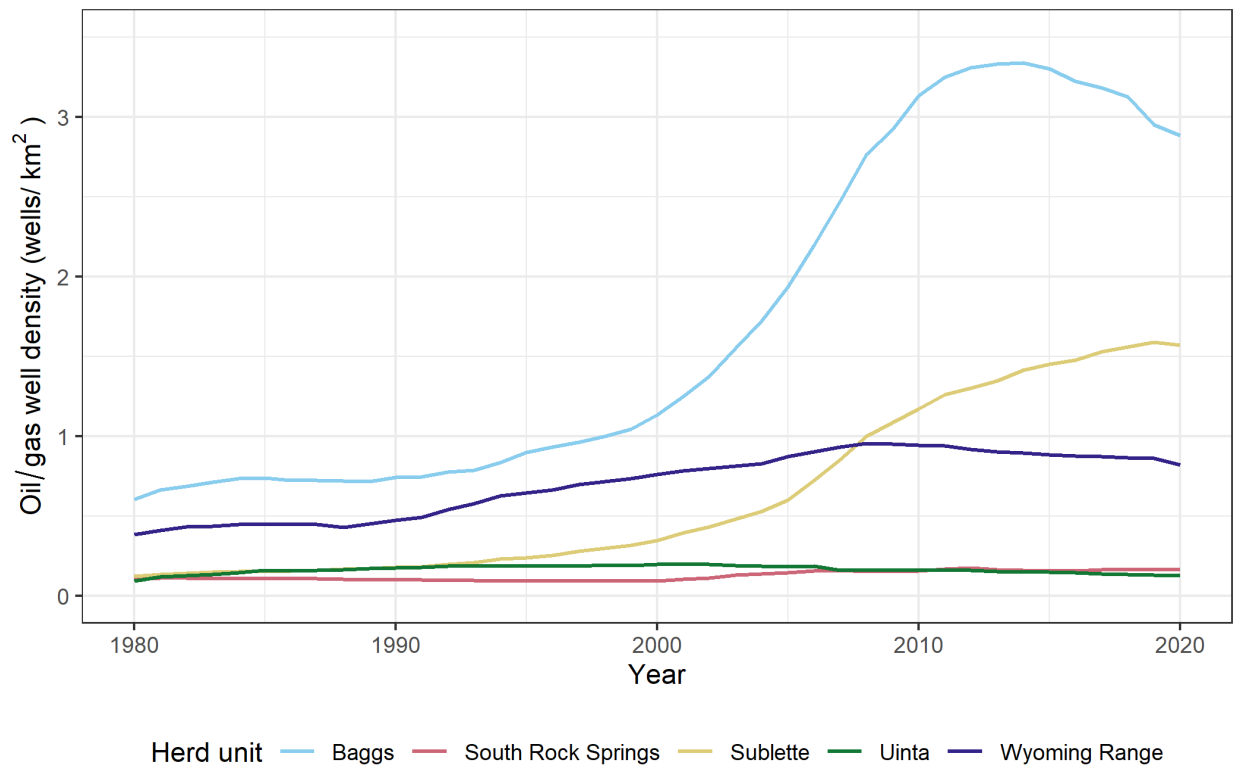


Fig. 23. Operational oil/gas well density (wells/km²) over time by mule deer herd unit in Wyoming, USA.

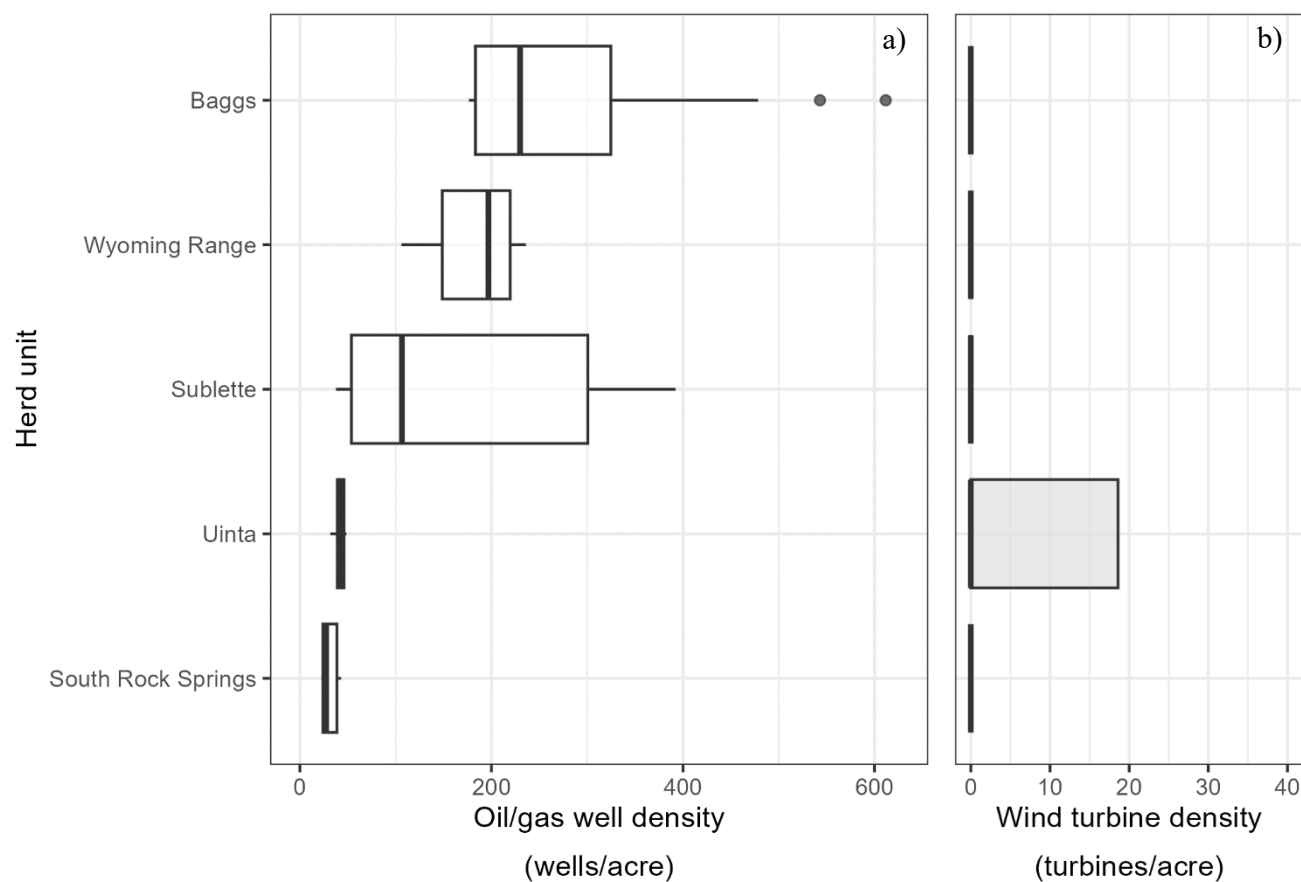


Fig. 24. Spatial variability in density of (a) oil/gas wells and (b) wind turbines in mule deer winter-use areas in Green River Wyoming Game and Fish Department (WGFD) region, 1985-2019, Wyoming, USA. Boxplots are on different scales and both show first quartile, median, and third quartile of data, with whiskers extending to the largest value within $1.5 * \text{IQR}$ (interquartile range) and outliers plotted as individual points.

Cody region

Winter-use areas

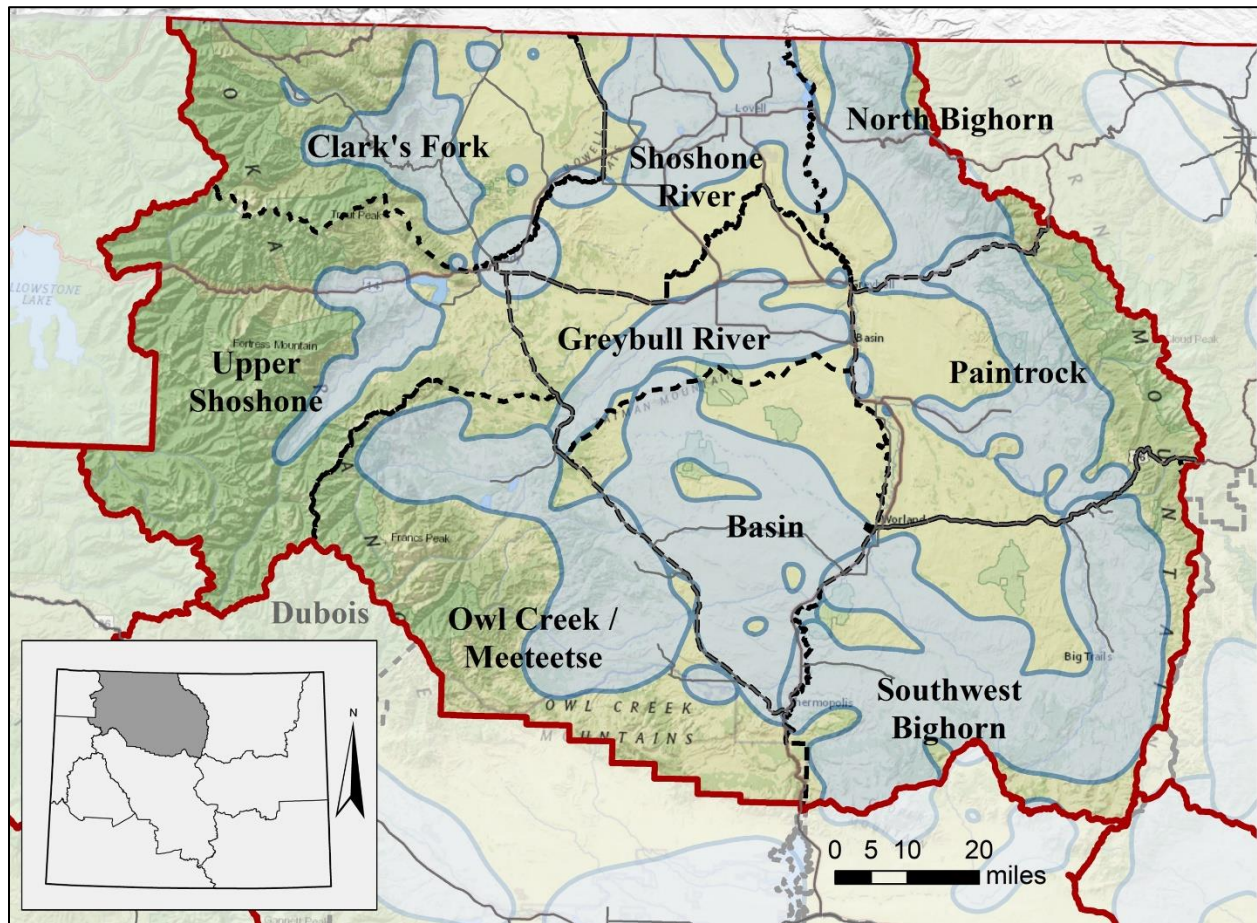


Fig. 25. Mule deer herd units delineated by dashed black lines (bold text), regions delineated by solid red lines, and winter-use areas (blue polygons) within Cody region of Wyoming Game and Fish Department (WGFD, State of Wyoming 2020). Roads shown as grey lines. Inset map shows region location in relation to the state. National Geographic World Map basemap credit: Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Recruitment

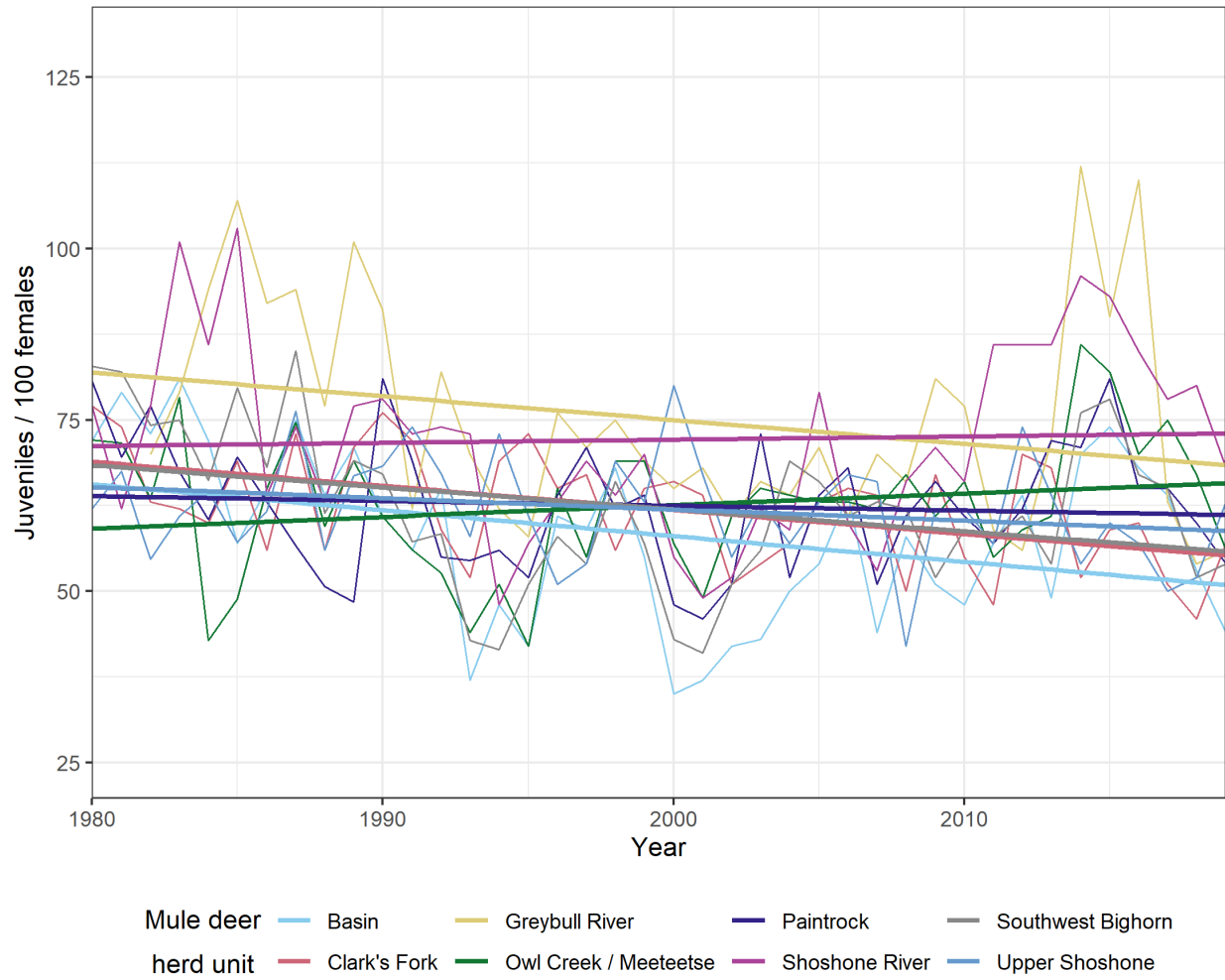


Fig. 26. Mule deer age ratios (proportion of juveniles/100 adult females) by herd unit in Cody Wyoming Game and Fish Department (WGFD) region, 1980–2019, Wyoming, USA.

Changes in landscape variables

Trends by herd unit

In the Cody region, agriculture, drought, and oil and gas wells had large changes in some or all herd units (Table 3).

Table 3. Trends from linear regression for landscape variables in mule deer herd units from 1980-2019, Wyoming, USA. Values represent relative effects and are scaled so variables can be directly compared. Bolded values represent trends that are statistically significant ($p \leq 0.05$). Significant trends are also summarized as: *large increase* ++ (≥ 0.01), *increase* + (> 0), *decrease* - (≥ -0.01), or *large decrease* -- (≤ -0.01). Ag = agriculture.

	Basin	Clark's Fork	Greybull River	Owl Creek / Meeteetse	Paintrock	Shoshone River	Southwest Bighorn	Upper Shoshone
Ag	-0.008 -	-0.007 -	0.0114	-0.024 --	0.002	-0.016 --	-0.003 -	-0.010 --
Drought	0.323 ++	0.207 ++	0.560 ++	0.311 ++	0.242 ++	0.408 ++	0.164 ++	0.193 ++
Oil/gas wells	-0.0003 -	0.0002	0.0009	-0.005 -	-0.0005	-0.004 -	0.0042 +	-0.0003 -
Shrubland	-0.025	0.023	-0.039 --	-0.007	-0.014	-0.025	-0.029	0.040 ++
Summer precipitation	0.352	-0.572	-0.004	-0.582	-0.913	-0.052	-0.273	-0.376
Wind	NA	NA	NA	NA	NA	NA	NA	NA
Winter temperatures	-0.020	0.022	-0.005	0.0276	0.0319	-0.017	0.003	0.045 ++

Land use

Although land use proportion was relatively stable over time, the amount of shrubland and agriculture varied across herd units. Shrubland includes bitterbrush shrub steppe, desert shrub, greasewood fans and flats, mesic upland shrub, saltbush fans and flats, and xeric upland shrub. Agriculture is defined as cropland, hay land, and food production excluding rangeland.

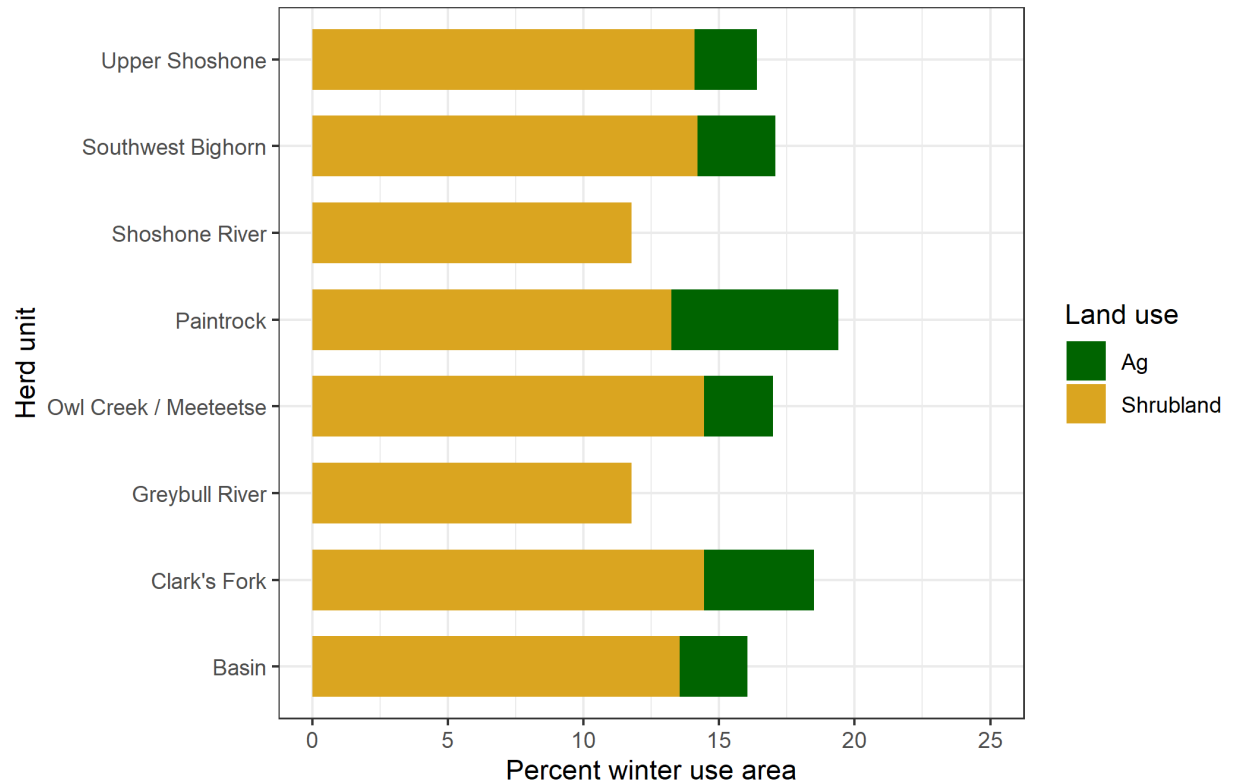


Fig. 27. Mean proportion of agriculture and shrubland in winter-use areas for 1985-2019 by mule deer herd unit in Cody Wyoming Game and Fish Department (WGFD) region, Wyoming, USA.

Average winter temperature (December-March of previous year)

Mean winter temperatures across herd units varied over time. The mean temperature in winter-use areas differed by herd units, but patterns tracked closely between herd units.

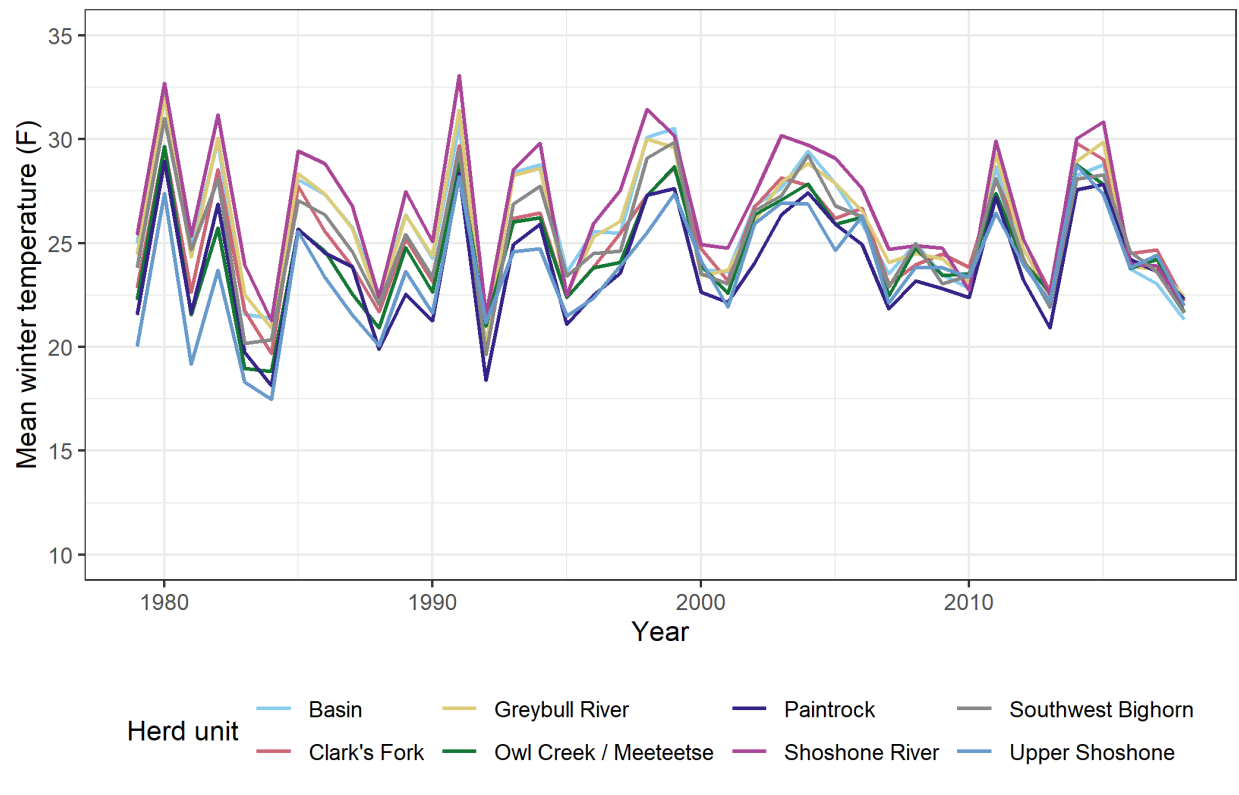


Fig. 28. Mean temperature (°F) in winter-use areas of mule deer herd units in Cody Wyoming Game and Fish Department (WGFD) region, 1980–2019, Wyoming, USA.

Summer precipitation (May-August of the previous year)

Precipitation during May-August of the year before counts varied considerably across herd units over time. Winter-use areas in Shoshone River, Greybull, and Basin herd units had consistently less precipitation than other herd units, although fluctuations in summer rainfall generally tracked between herd units in the region.

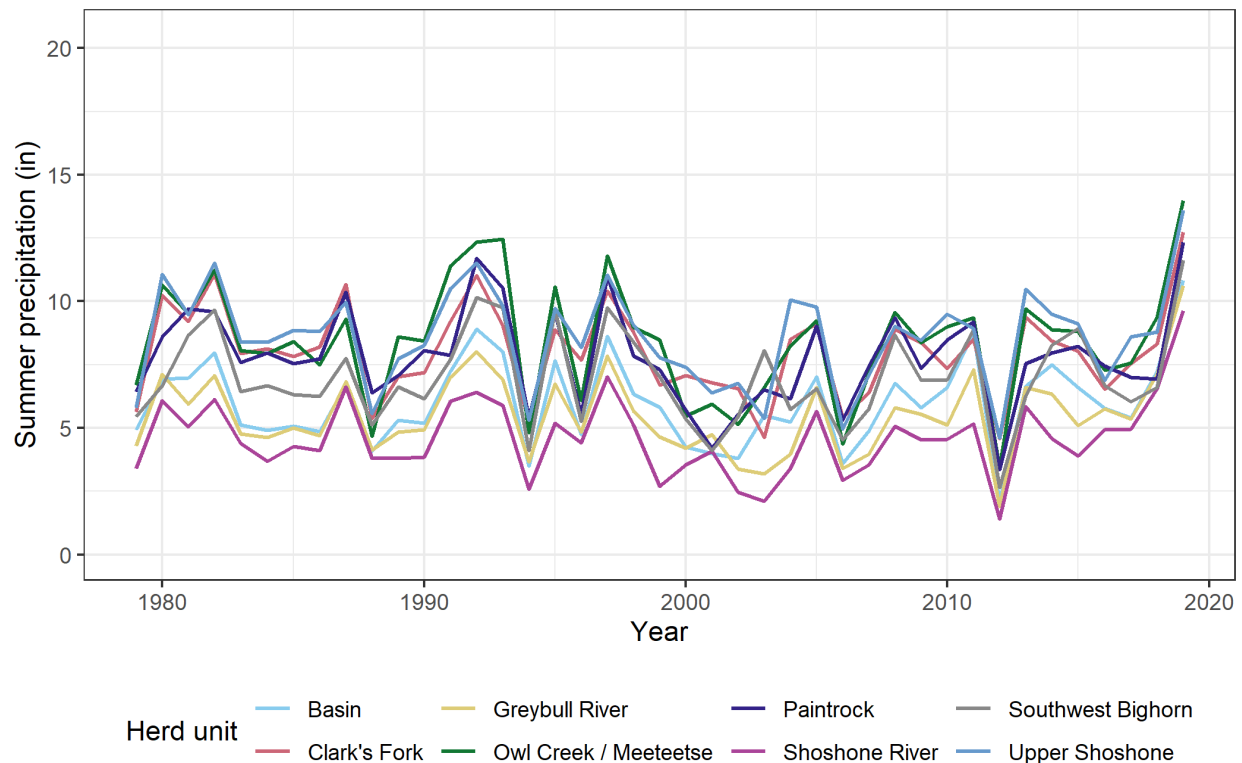


Fig. 29. Mean precipitation (inches) during the previous May-August in winter-use areas of mule deer herd units in Cody Wyoming Game and Fish Department (WGFD) region, 1980–2019, Wyoming, USA.

Cumulative drought

Cumulative drought (the number of months with severe drought) across herd units varied over time but patterns of drought occurrence were similar between herd units. Shoshone River experienced the longest periods of cumulative drought, with similar drought patterns in Greybull River and Basin herd units. Some herd units experienced fewer months of cumulative drought during periods of low rainfall in the Cody region (e.g., Paintrock and Upper Shoshone during the early 1990s and Clark's Fork between 2001-2010), but no herd unit in the region was consistently buffered from drought.

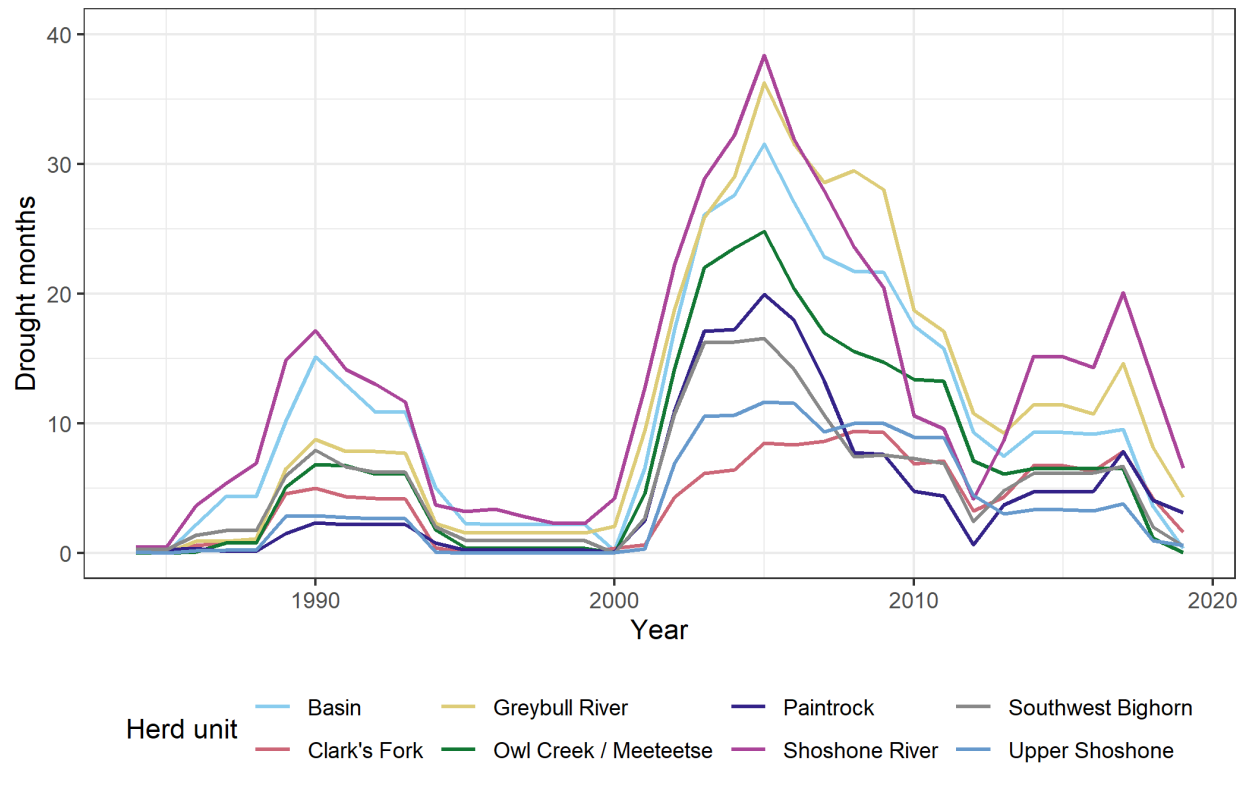


Fig. 30. Cumulative drought (months of severe drought during the previous 5 years) in mule deer winter-use areas within herd units in Cody Wyoming Game and Fish Department (WGFD) region, 1985-2019, Wyoming, USA.

Changes in energy development density

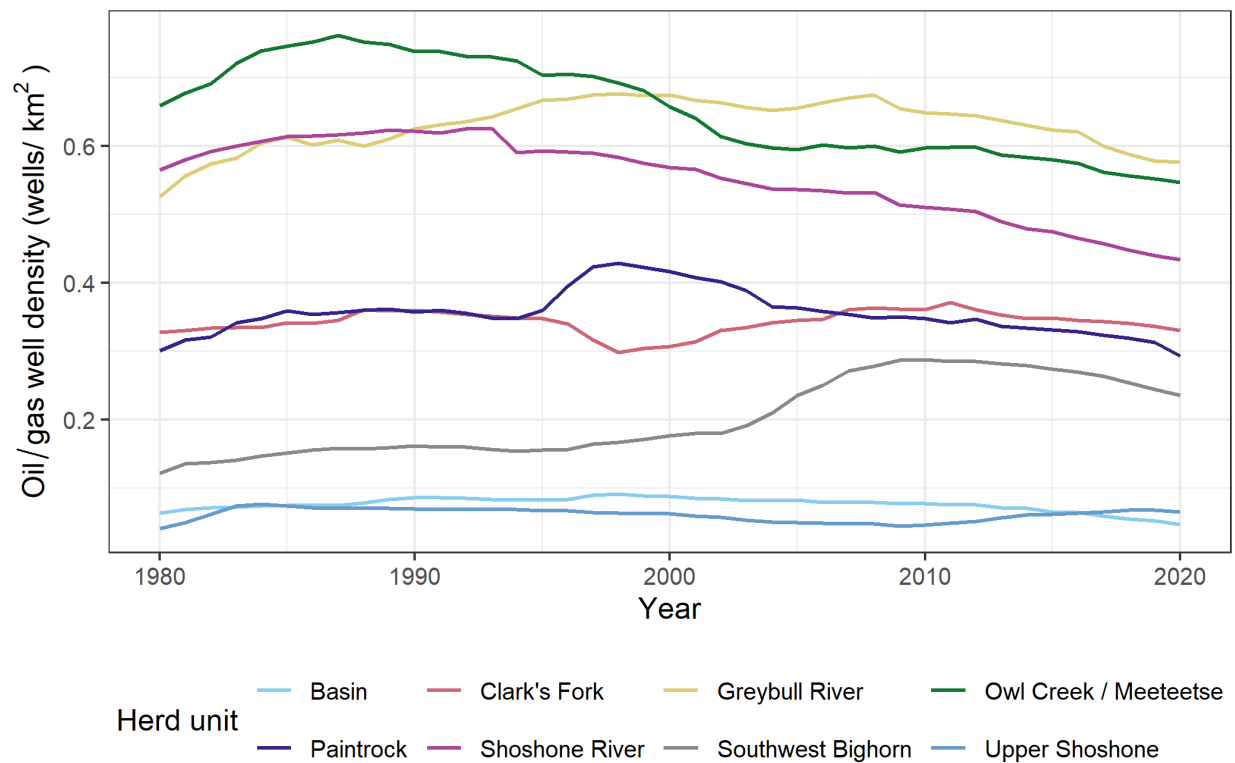


Fig. 31. Operational oil/gas well density (wells/km²) over time by mule deer herd unit in Wyoming, USA.

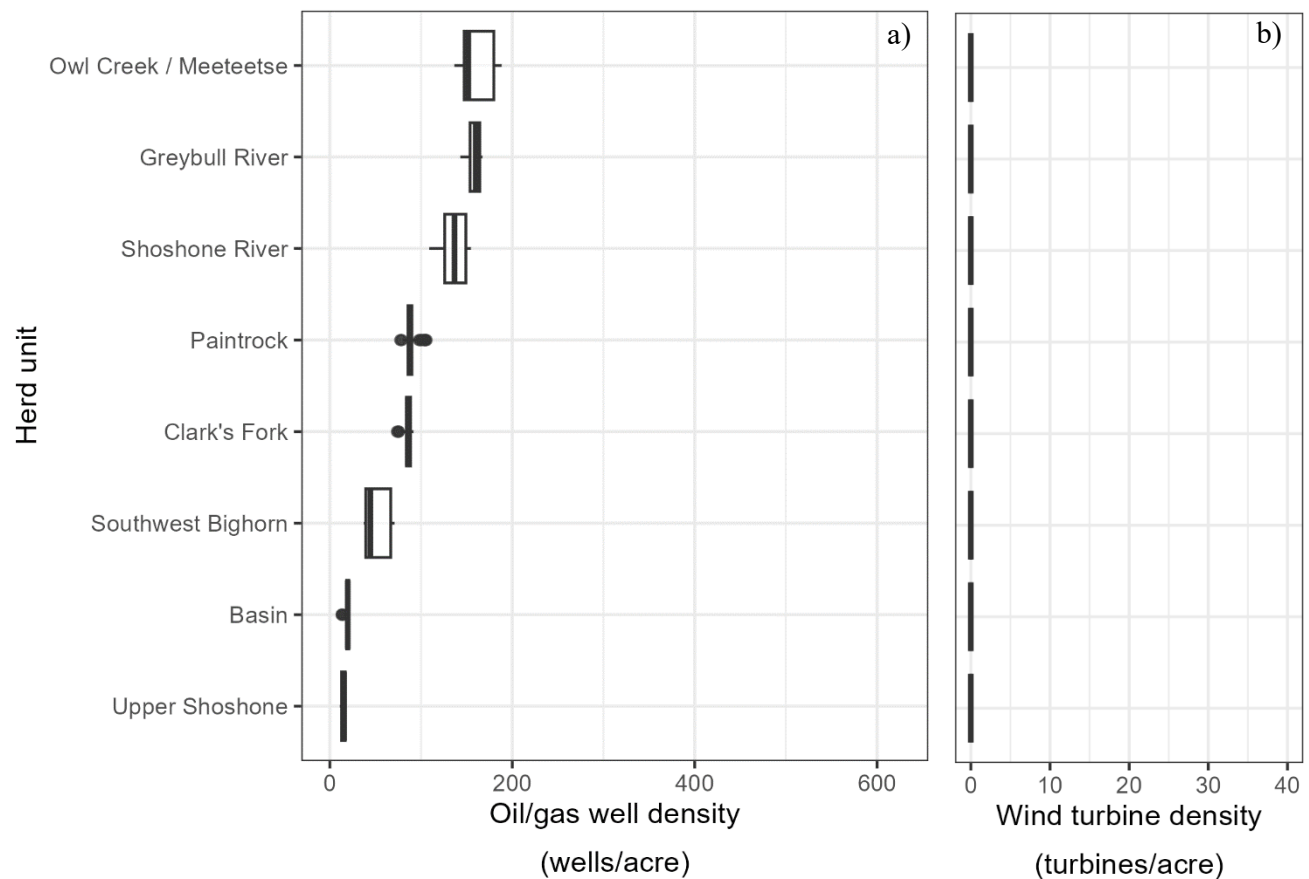


Fig. 32. Spatial variability in density of (a) oil/gas wells and (b) wind turbines in mule deer winter-use areas in Cody Wyoming Game and Fish Department (WGFD) region, 1985-2019, Wyoming, USA. Boxplots are on different scales and both show first quartile, median, and third quartile of data, with whiskers extending to the largest value within $1.5 * \text{IQR}$ (interquartile range) and outliers plotted as individual points.

Lander region

Winter-use areas

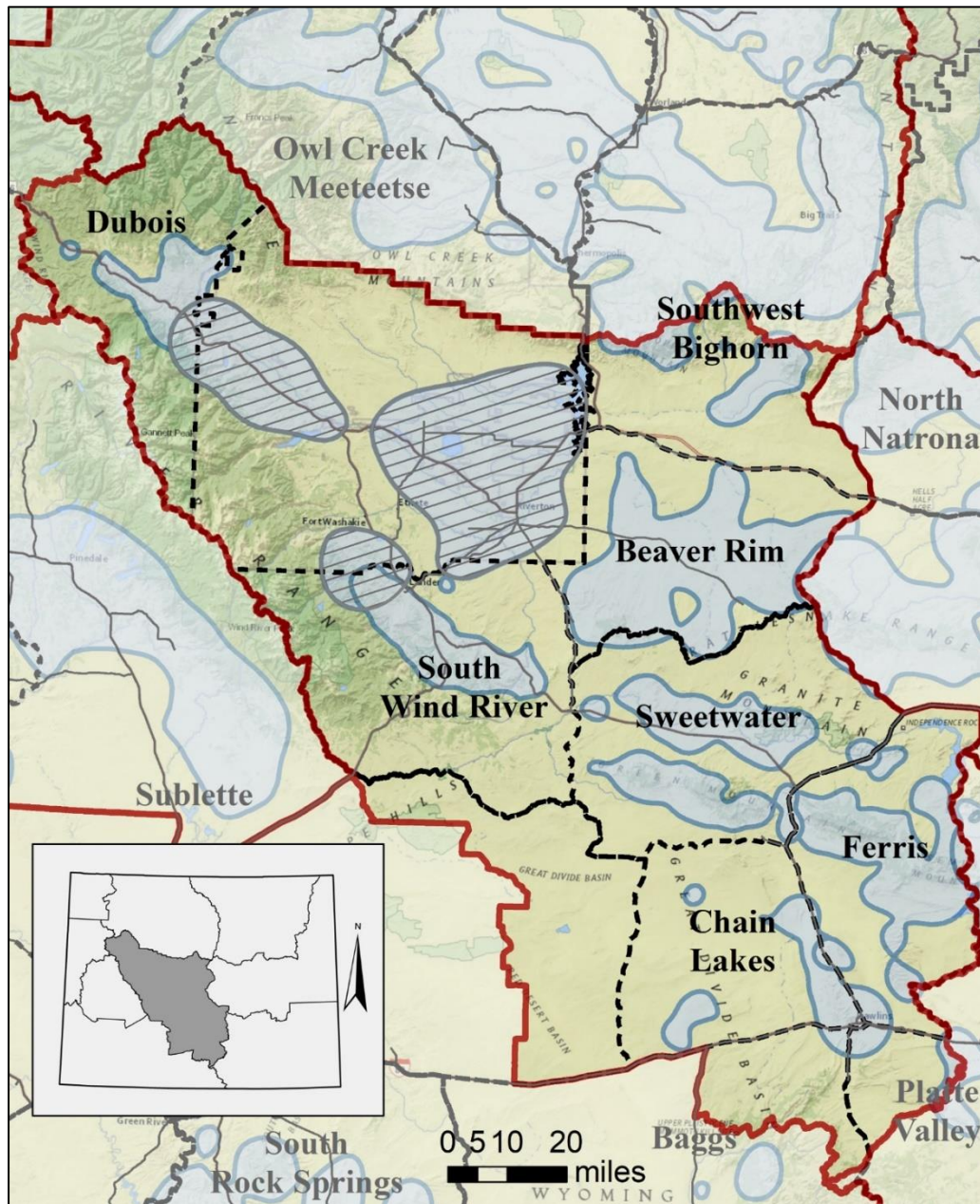


Fig. 33. Mule deer herd units delineated by dashed black lines (bold text), regions delineated by solid red lines, and winter-use areas (blue polygons) within Lander region of Wyoming Game and Fish Department (WGFD, State of Wyoming 2020). Analysis excludes the Project herd area (hatched polygon), which does not have consistent long-term age-ratio data. Roads shown as grey lines. Inset map shows region location in relation to the state. National Geographic World Map basemap credit: Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Recruitment

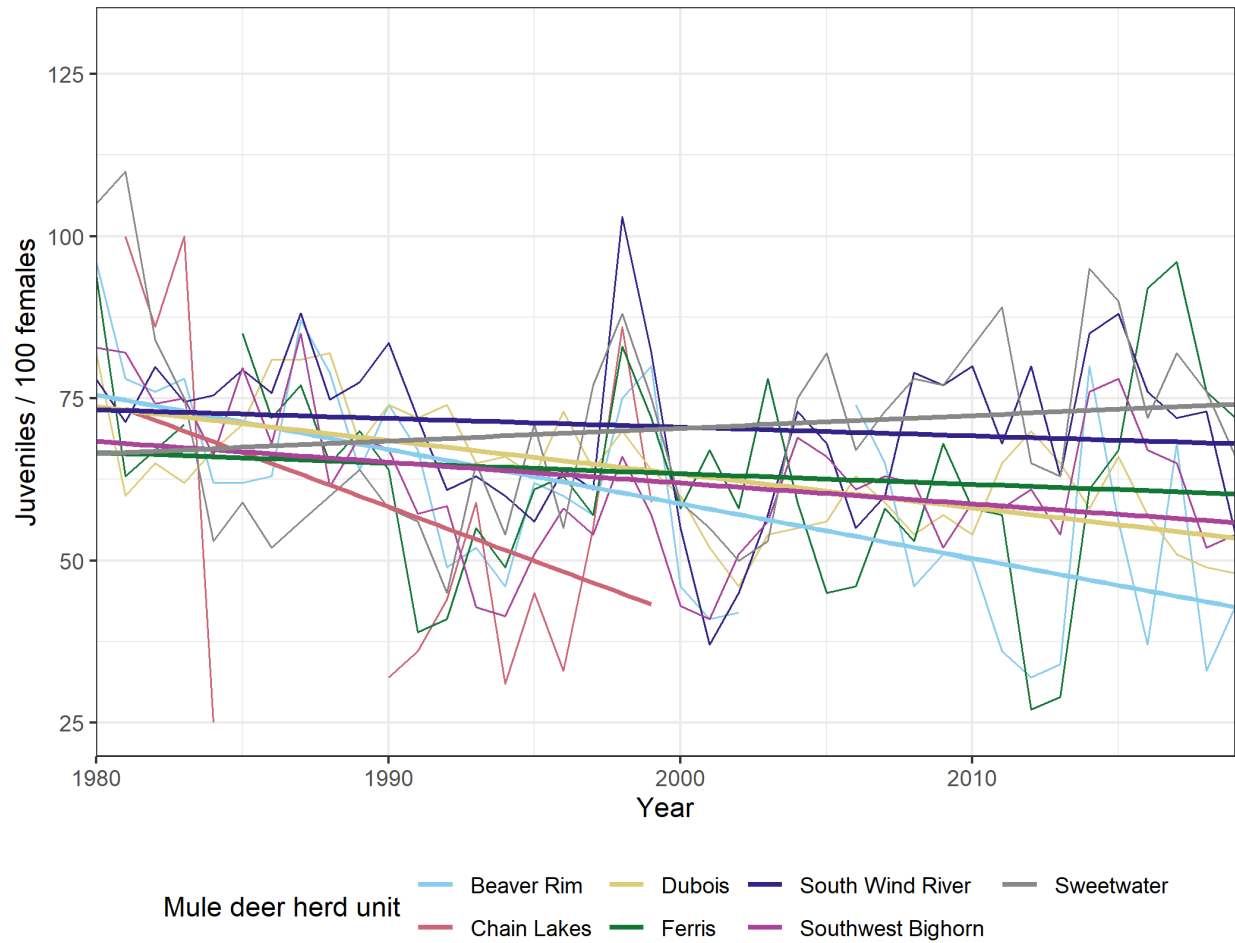


Fig. 34. Mule deer age ratios (proportion of juveniles/100 adult females) by herd unit in Lander Wyoming Game and Fish Department (WGFD) region, 1980–2019, Wyoming, USA. Chain Lakes has limited age ratio data to inform the trend (14 years available: 1981-1984, 1990-1999). Project herd unit is not shown because consistent long-term age-ratio data was not available.

Changes in landscape variables

Trends by herd unit

In the Lander region, agriculture, winter temperatures, drought, and oil and gas wells had large changes in some herd units (Table 4).

Table 4. Trends from linear regression for landscape variables in mule deer herd units from 1980-2019, Wyoming, USA. Values represent relative effects and are scaled so variables can be directly compared. Bolded values represent trends that are statistically significant ($p \leq 0.05$). Significant trends are also summarized as: *increase* + (>0), *large increase* ++ (≥ 0.01), *decrease* - (≥ -0.01), or *large decrease* -- (≤ -0.01). Ag = agriculture.

	Beaver Rim	Chain Lakes	Dubois	Ferris	South Wind River	Southwest Bighorn	Sweetwater
Ag	0.001 +	-0.00003	-0.014 --	0.002 +	-0.001	-0.003 -	0.010 ++
Drought	0.107	0.344 ++	0.143	0.329 ++	0.376 ++	0.164 ++	0.412 ++
Oil/gas wells	0.001 +	0.035 ++	-0.0001 -	-0.0002	0.001 +	0.004 +	-0.001 -
Shrubland	-0.004	-0.003	0.018	-0.005	-0.029	-0.029	-0.014
Summer precipitation	0.879	-0.131	-0.462	-0.378	0.784	-0.273	0.286
Wind	NA	0.0001 +	NA	NA	NA	NA	NA
Winter temperatures	0.001	0.034	0.071 ++	0.026	0.035	0.003	0.021

Land use

Although land use proportion was relatively stable over time, the amount of shrubland and agriculture varied across herd units. Shrubland includes bitterbrush shrub steppe, desert shrub, greasewood fans and flats, mesic upland shrub, saltbush fans and flats, and xeric upland shrub. Agriculture is defined as cropland, hay land, and food production excluding rangeland.

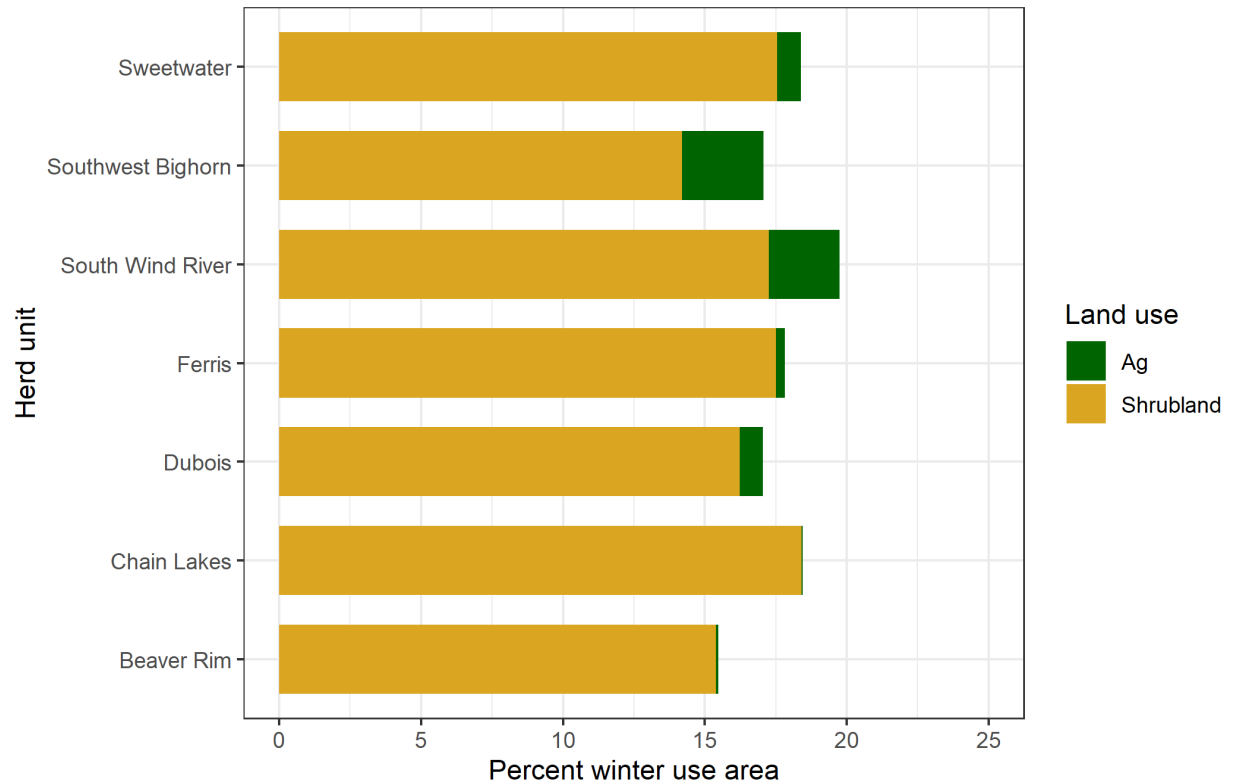


Fig. 35. Mean proportion of agriculture and shrubland in winter-use areas for 1985-2019 by mule deer herd unit in Lander Wyoming Game and Fish Department (WGFD) region, Wyoming, USA.

Average winter temperature (December-March of previous year)

Mean winter temperatures across herd units varied over time. The mean temperature in winter-use areas differed by herd units, but patterns tracked closely between herd units.

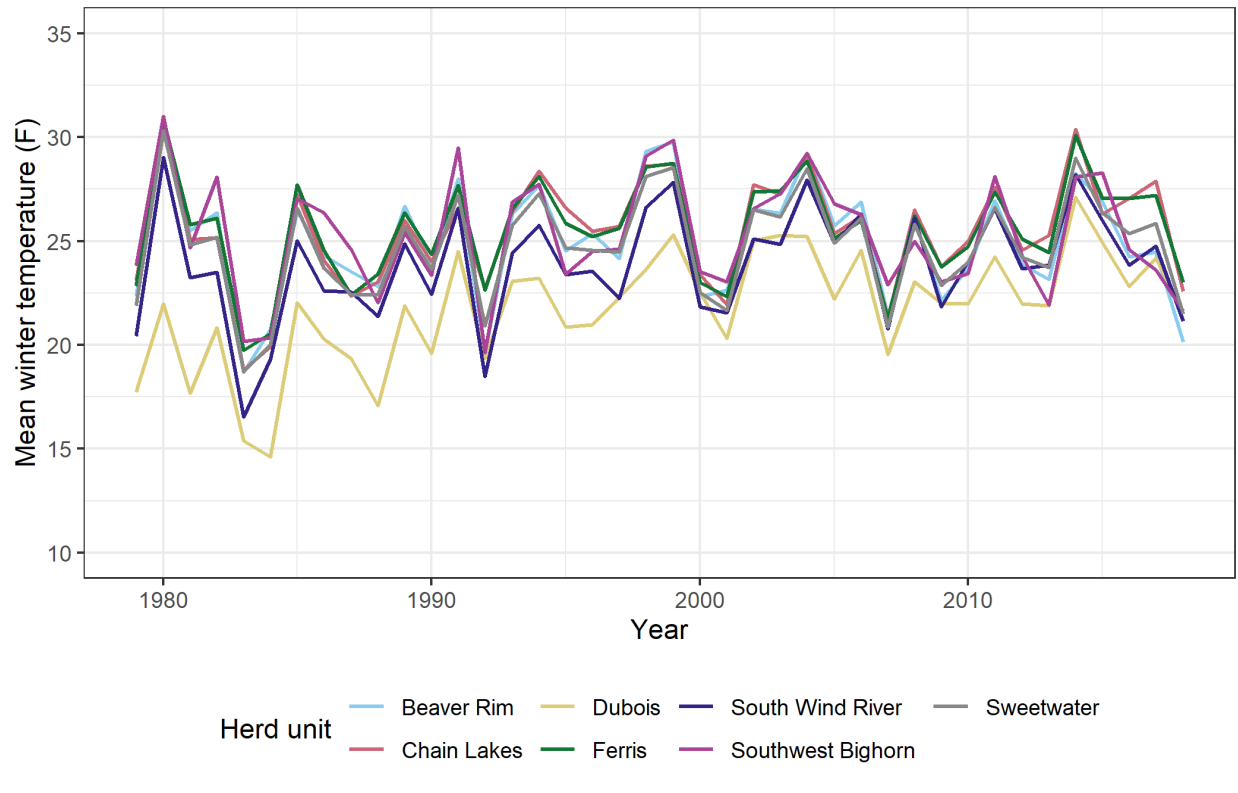


Fig. 36. Mean temperature (°F) in winter-use areas of mule deer herd units in Lander Wyoming Game and Fish Department (WGFD) region, 1980–2019, Wyoming, USA.

Summer precipitation (May-August of the previous year)

Precipitation during May-August of the year before counts varied over time, but fluctuations in precipitation were similar between herd units.

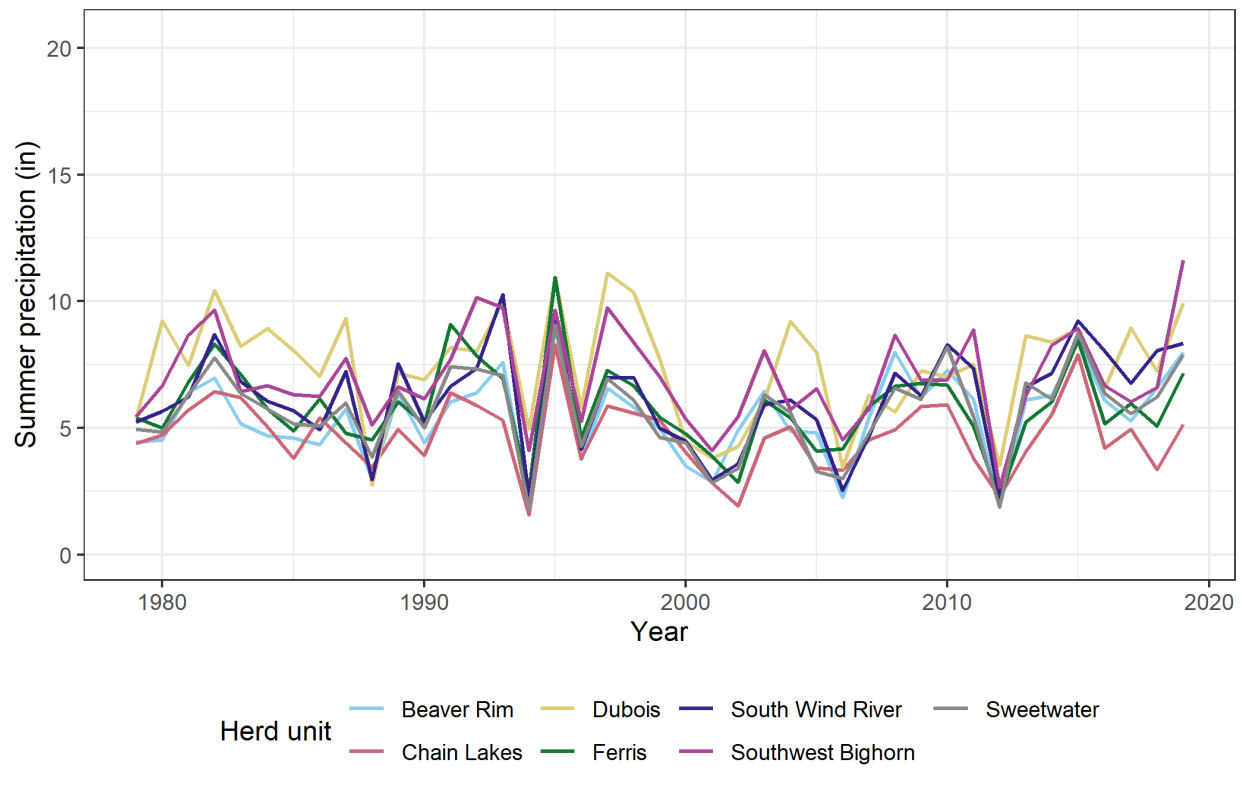


Fig. 37. Mean precipitation (inches) during the previous May-August in winter-use areas of mule deer herd units in Lander Wyoming Game and Fish Department (WGFD) region, 1980–2019, Wyoming, USA.

Cumulative drought

Cumulative drought (the number of months with severe drought) across herd units varied over time but patterns of drought occurrence were similar between herd units. Beaver Rim herd unit had more months of cumulative drought than other herd units during the early 1990s. All herd units in the region experienced varying levels of drought between 2001-2017.

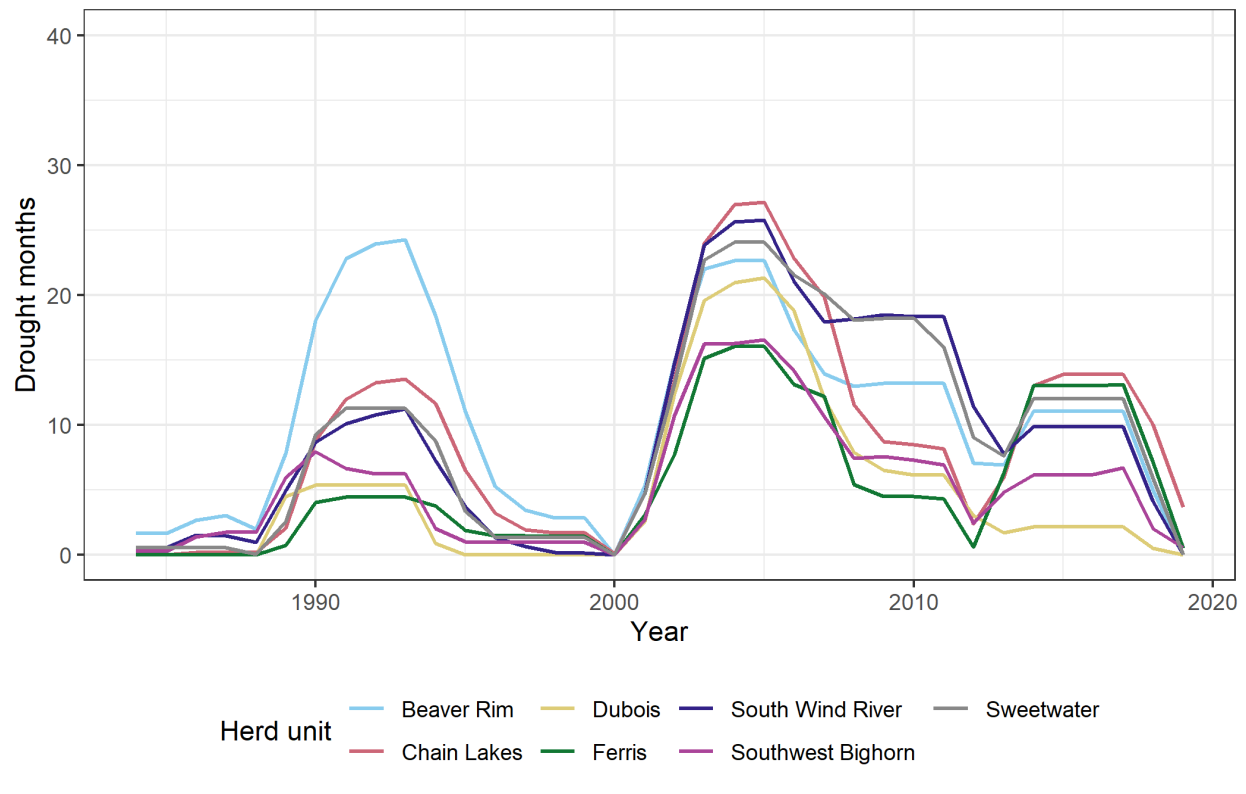


Fig. 38. Cumulative drought (months of severe drought during the previous 5 years) in mule deer winter-use areas within herd units in Lander Wyoming Game and Fish Department (WGFD) region, 1985-2019, Wyoming, USA.

Changes in energy development density

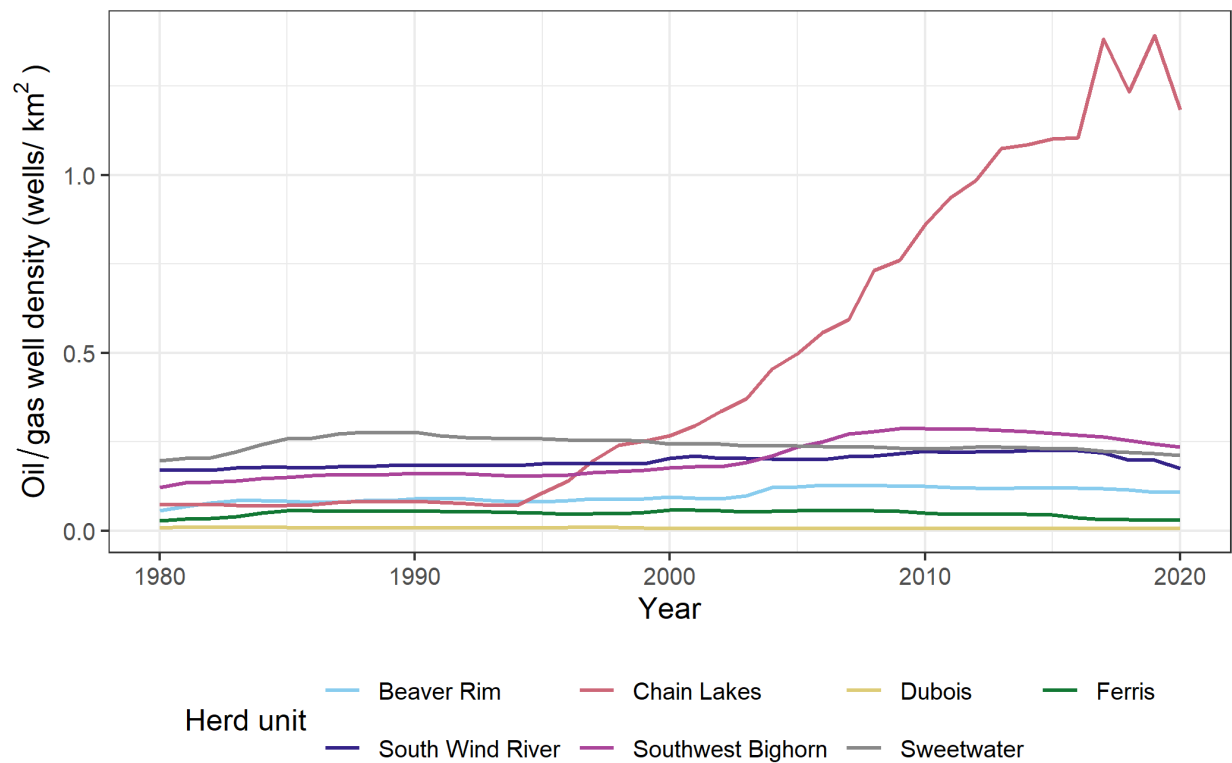


Fig. 39. Operational oil/gas well density (wells/km²) over time by mule deer herd unit in Wyoming, USA.

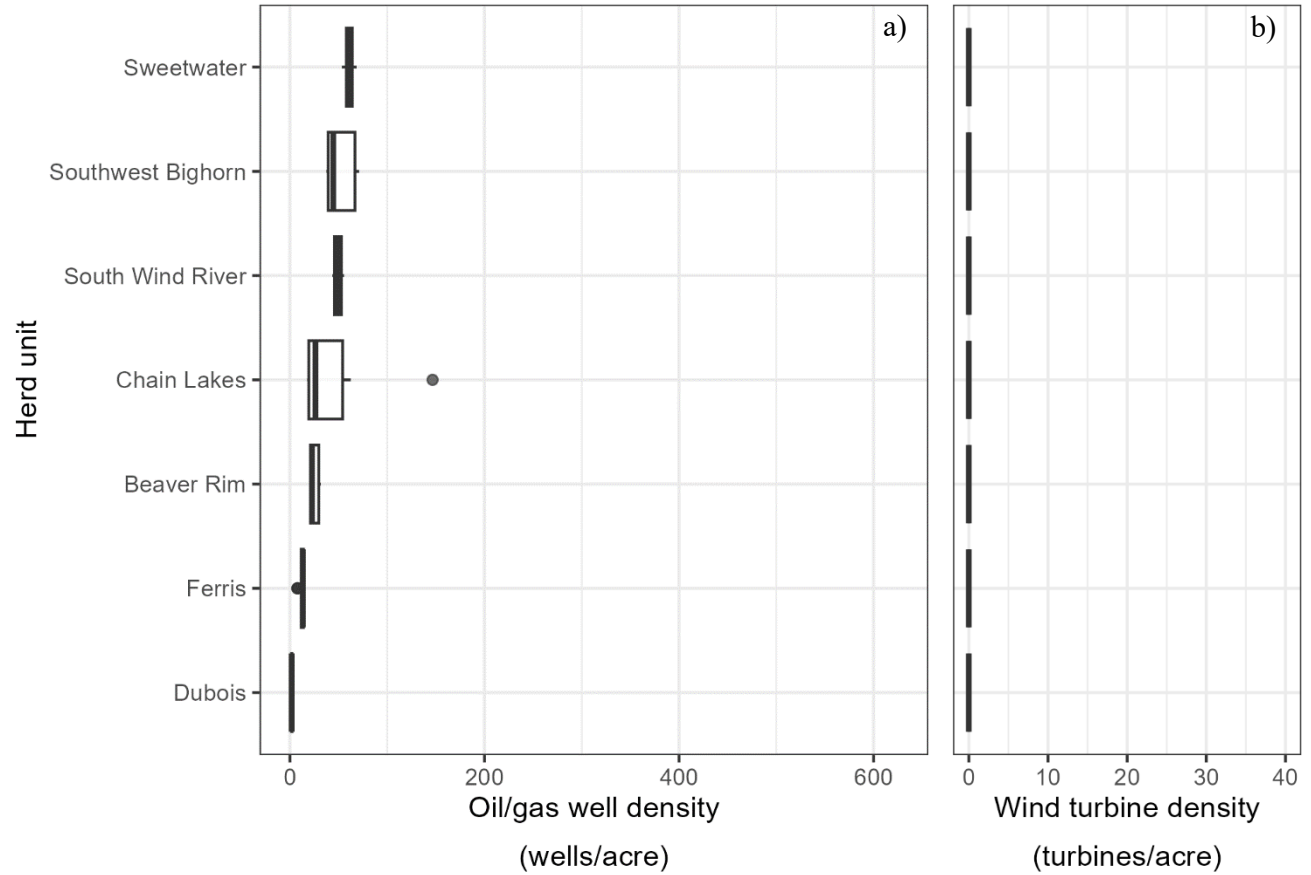


Fig. 40. Spatial variability in density of (a) oil/gas wells and (b) wind turbines in mule deer winter-use areas in Lander Wyoming Game and Fish Department (WGFD) region, 1985-2019, Wyoming, USA. Boxplots are on different scales and both show first quartile, median, and third quartile of data, with whiskers extending to the largest value within $1.5 \times \text{IQR}$ (interquartile range) and outliers plotted as individual points.

Sheridan region

Winter-use areas

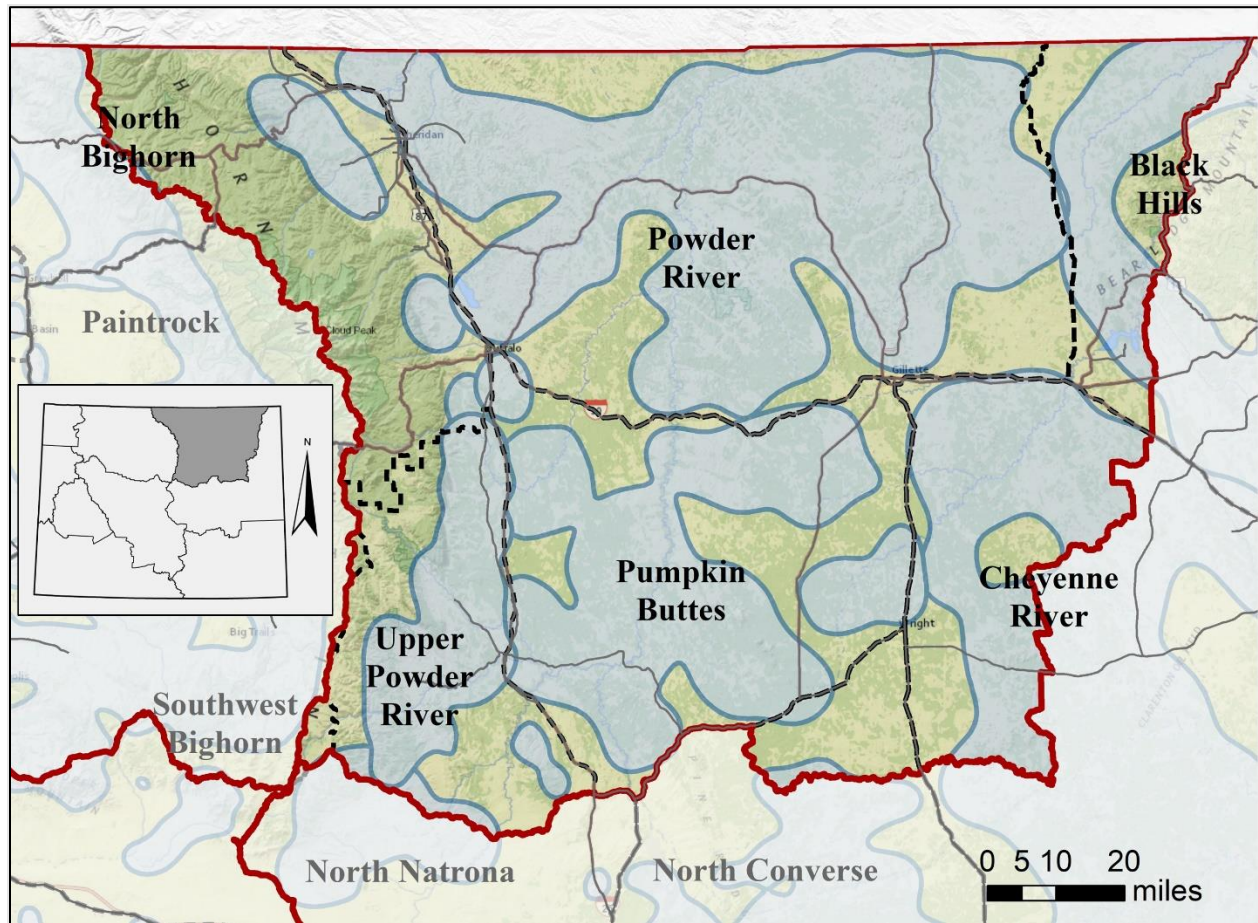


Fig. 41. Mule deer herd units delineated by dashed black lines (bold text), regions delineated by solid red lines, and winter-use areas (blue polygons) within Sheridan region of Wyoming Game and Fish Department (WGFD, State of Wyoming 2020). Roads shown as grey lines. Inset map shows region location in relation to the state. National Geographic World Map basemap credit: Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Recruitment

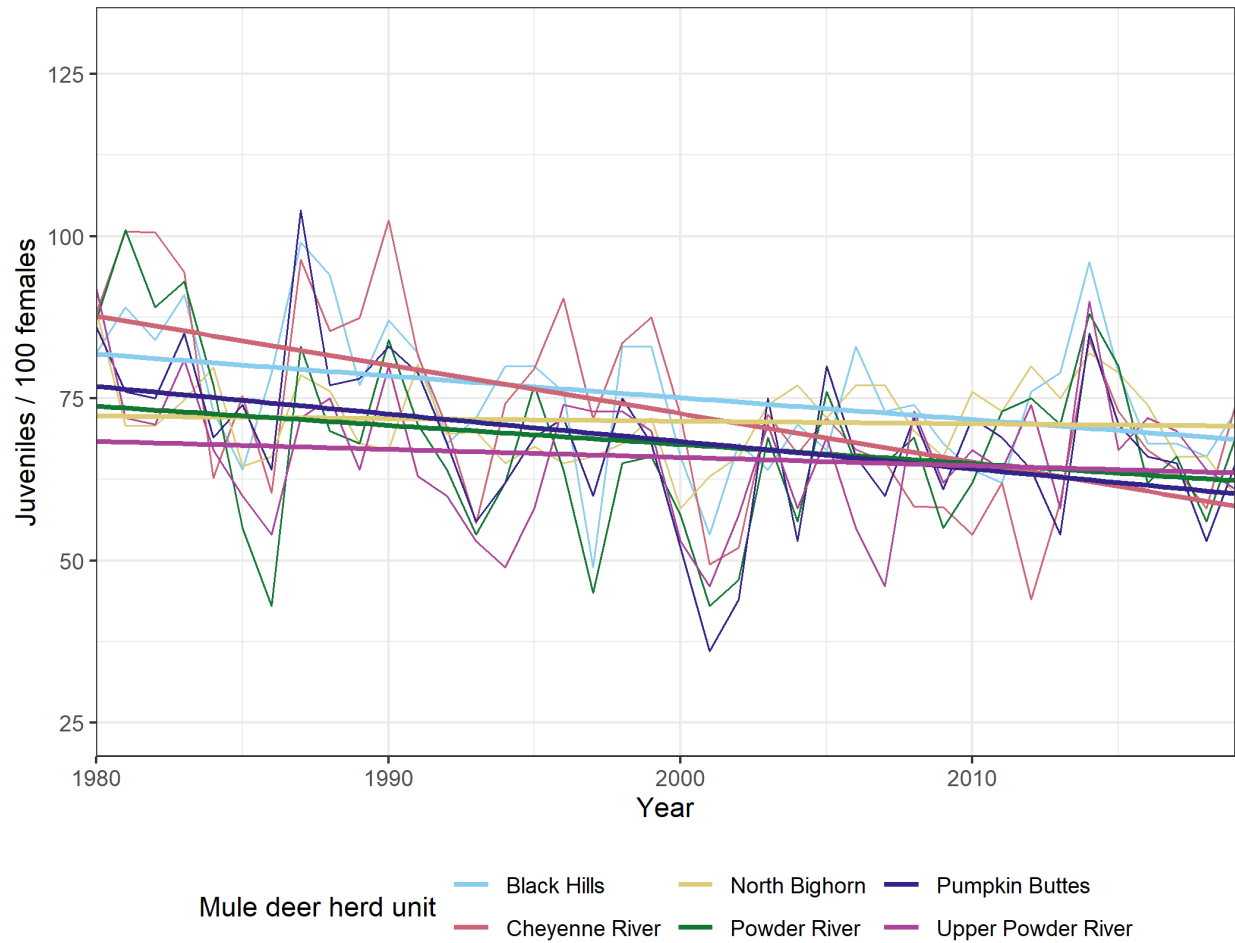


Fig. 42. Mule deer age ratios (proportion of juveniles/100 adult females) by mule deer herd unit in Sheridan Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Changes in landscape variables

Trends by herd unit

In the Sheridan region, agriculture, shrubland, drought, and oil and gas wells had large changes in many herd units (Table 5).

Table 5. Trends from linear regression for landscape variables in mule deer herd units from 1980-2019, Wyoming, USA. Values represent relative effects and are scaled so variables can be directly compared. Bolded values represent trends that are statistically significant ($p \leq 0.05$). Significant trends are also summarized as: *increase* + (>0), *large increase* ++ (≥ 0.01), *decrease* - (≥ -0.01), or *large decrease* -- (≤ -0.01). Ag = agriculture.

	Black Hills	Cheyenne River	North Bighorn	Powder River	Pumpkin Buttes	Upper Powder River
Ag	-0.021 --	-0.011 --	-0.032 --	-0.048 --	-0.0203 --	-0.018 --
Drought	0.059	0.270 ++	0.192 ++	0.116	0.127	0.159 ++
Oil/gas wells	-0.001 -	-0.001	-0.0001 -	0.035 ++	0.0495 ++	-0.001 -
Shrubland	0.001	-0.062 --	-0.011	0.015	-0.0319	-0.024
Summer precipitation	2.140	2.000	-0.144	1.100	1.210	0.148
Wind	NA	NA	NA	NA	NA	NA
Winter temperatures	0.008	0.006	0.029	0.0214	0.010	0.016

Land use

Although land use proportion was relatively stable over time, the amount of shrubland and agriculture varied across herd units. Shrubland includes bitterbrush shrub steppe, desert shrub, greasewood fans and flats, mesic upland shrub, saltbush fans and flats, and xeric upland shrub. Agriculture is defined as cropland, hay land, and food production excluding rangeland.

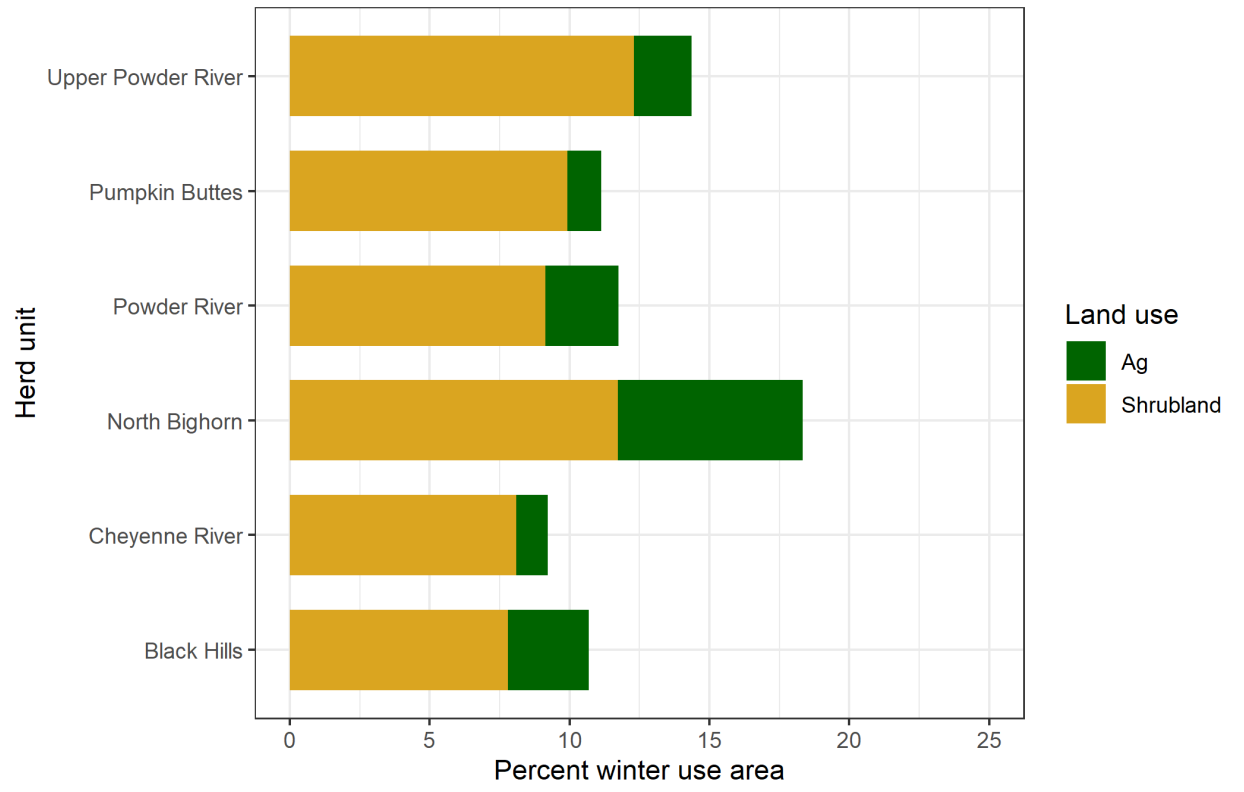


Fig. 43. Mean proportion of agriculture and shrubland in winter-use areas for 1985-2019 by mule deer herd unit in Sheridan Wyoming Game and Fish Department region, Wyoming, USA.

Average winter temperature (December-March of previous year)

Mean winter temperatures across herd units varied over time. The mean temperature in winter-use areas differed by herd units, but patterns tracked closely between herd units.

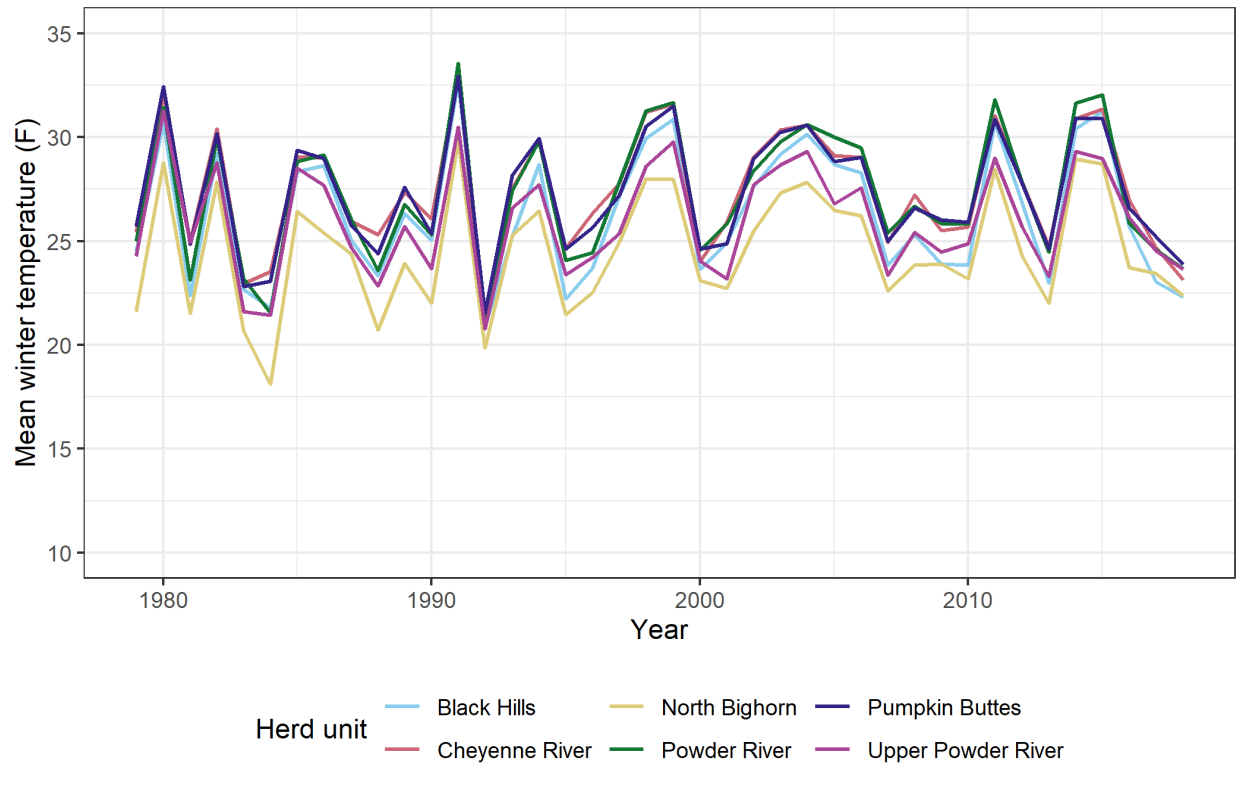


Fig. 44. Mean temperature (°F) in winter-use areas of mule deer herd units in Sheridan Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Summer precipitation (May-August of the previous year)

Precipitation during May-August of the year before counts varied over time, but fluctuations in summer precipitation were similar between herd units.

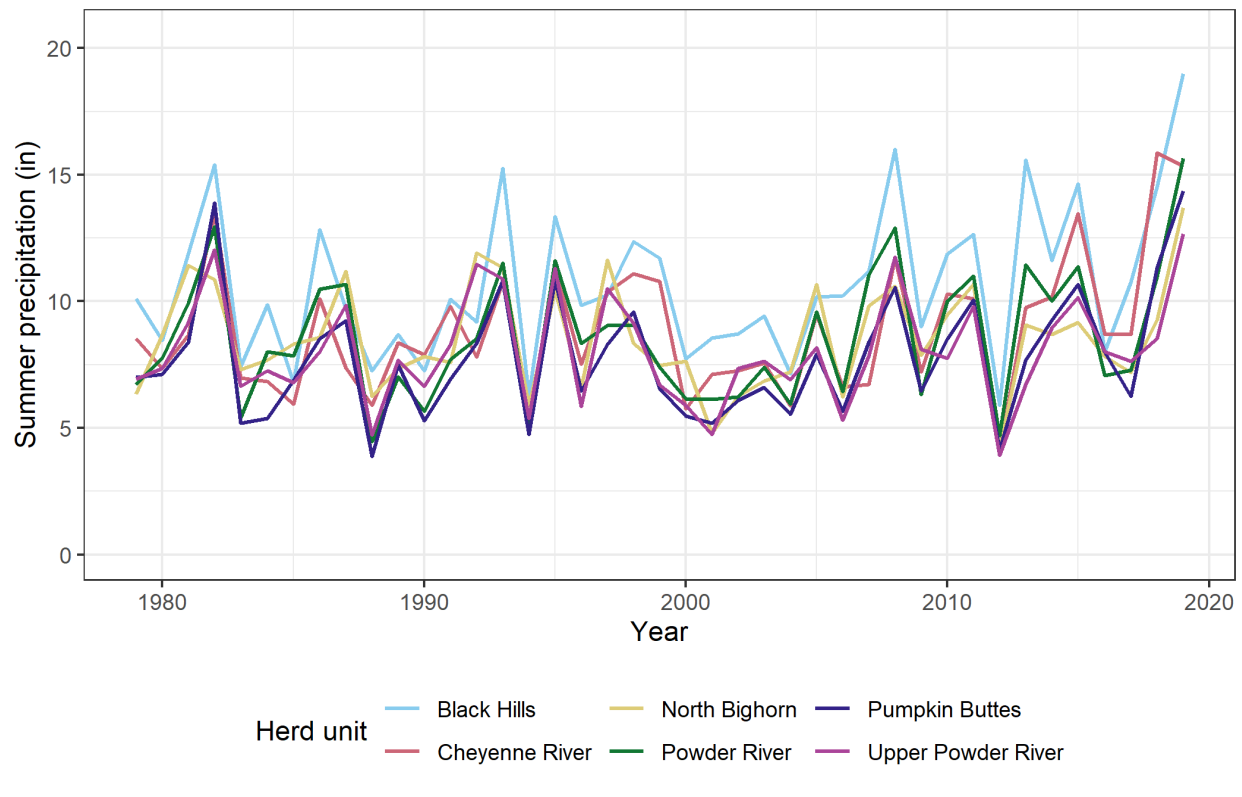


Fig. 45. Mean precipitation (inches) during the previous May-August in winter-use areas of mule deer herd units in Sheridan Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Cumulative drought

Cumulative drought (the number of months with severe drought) across herd units varied over time but patterns of drought occurrence were generally similar between herd units. Powder River, and several years later Cheyenne River, had more months of cumulative drought than other herd units during the early 2000s. All herd units in the region experienced varying levels of cumulative drought between 2001-2017.

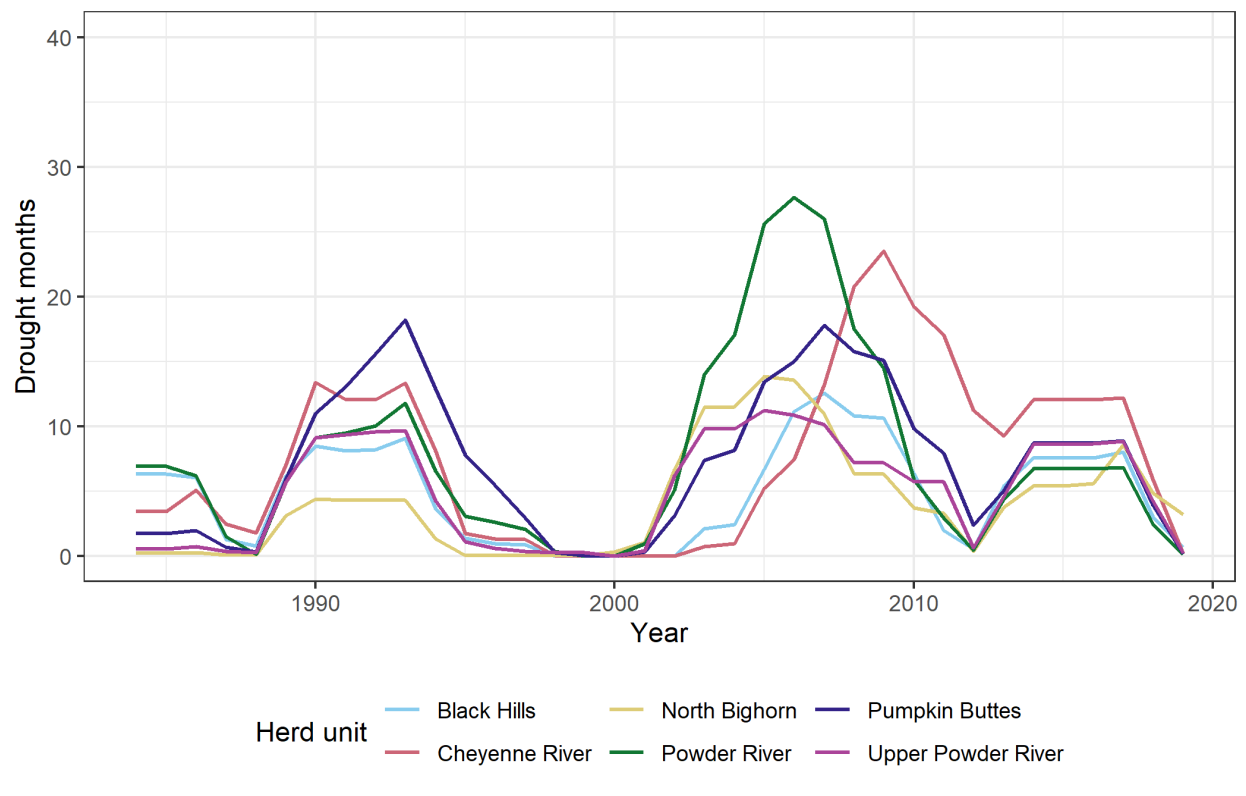


Fig. 46. Cumulative drought (months of severe drought during the previous 5 years) in mule deer winter-use areas within herd units in Sheridan Wyoming Game and Fish Department region, 1985-2019, Wyoming, USA.

Changes in energy development density

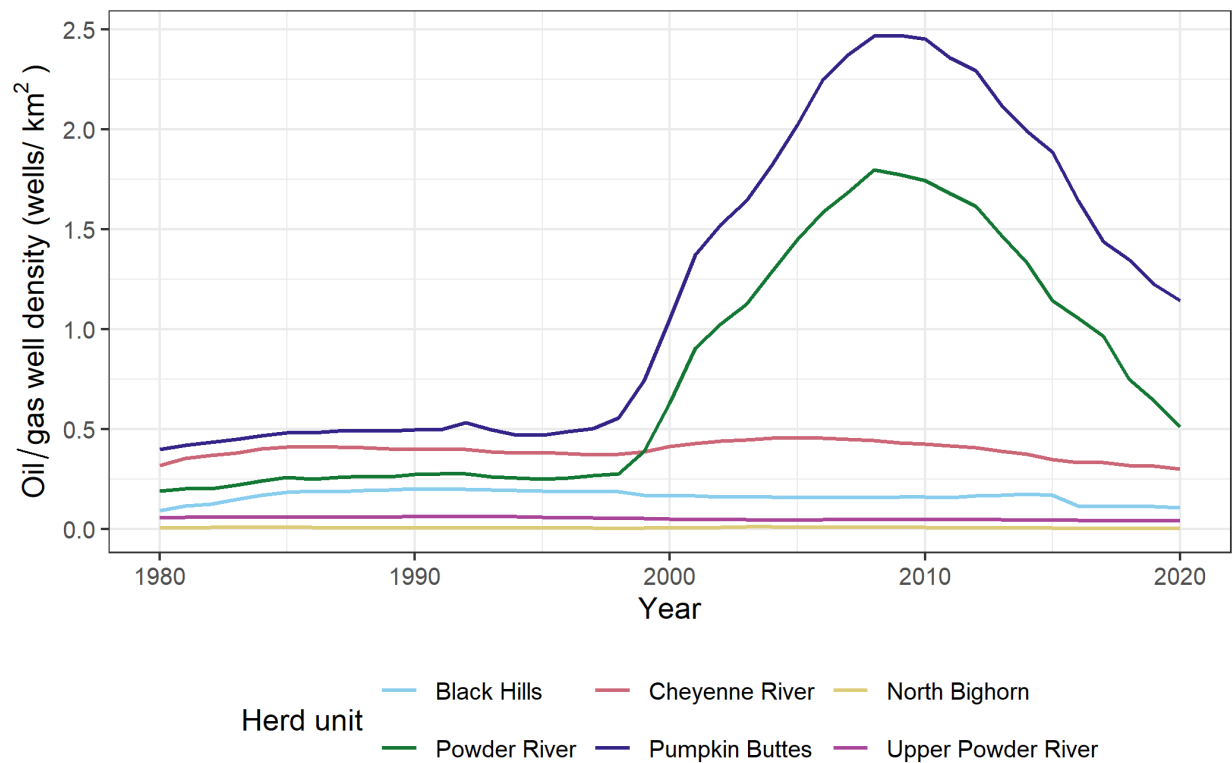


Fig. 47. Operational oil/gas well density (wells/km²) over time by mule deer herd unit in Wyoming, USA.

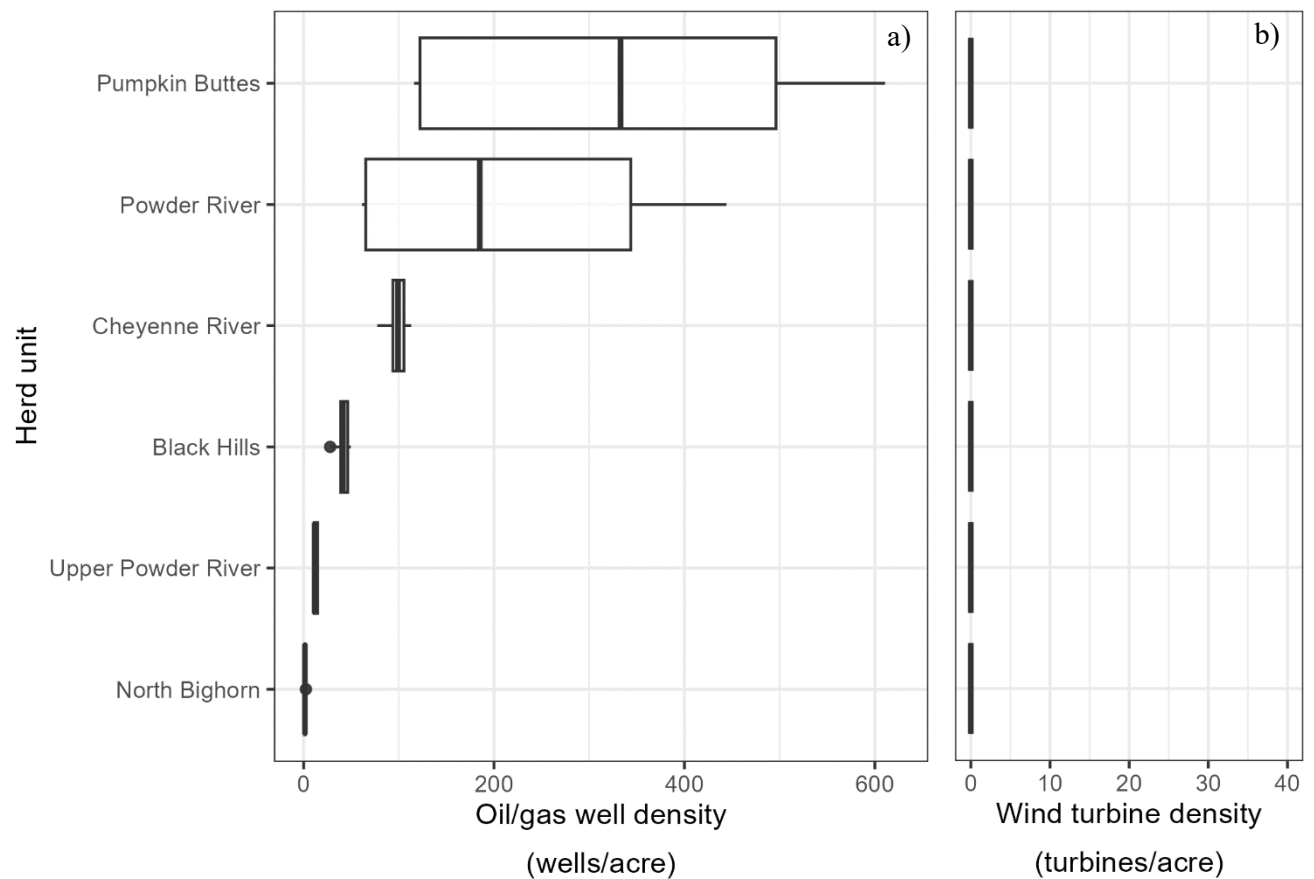


Fig. 48. Spatial variability in density of (a) oil/gas wells and (b) wind turbines in mule deer winter-use areas in Sheridan Wyoming Game and Fish Department (WGFD) region, 1985-2019, Wyoming, USA. Boxplots are on different scales and both show first quartile, median, and third quartile of data, with whiskers extending to the largest value within 1.5 * IQR (interquartile range) and outliers plotted as individual points.

Casper region

Winter-use areas

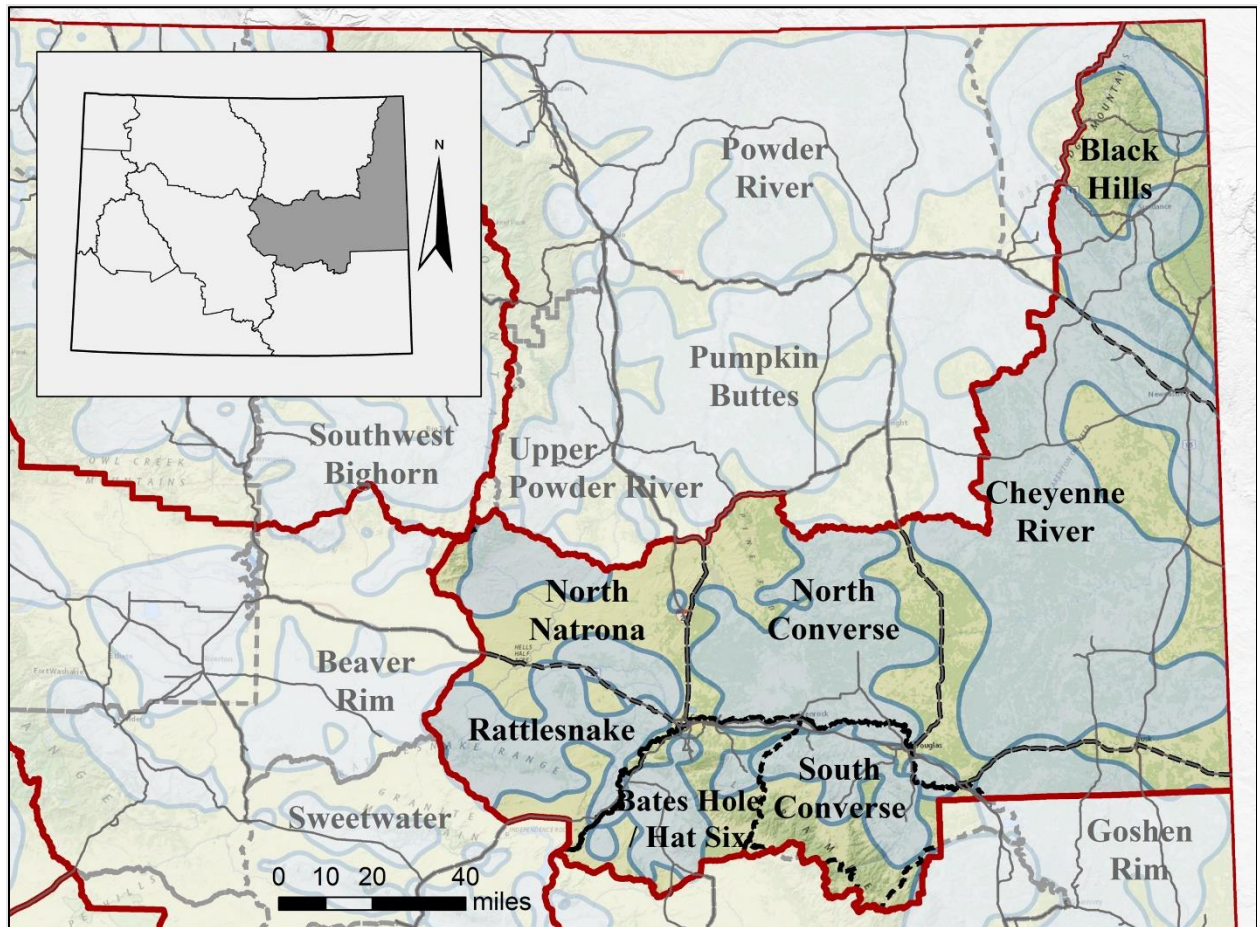


Fig. 49. Mule deer herd units delineated by dashed black lines (bold text), regions delineated by solid red lines, and winter-use areas (blue polygons) within Casper region of Wyoming Game and Fish Department (WGFD, State of Wyoming 2020). Roads shown as grey lines. Inset map shows region location in relation to the state. National Geographic World Map basemap credit: Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Recruitment

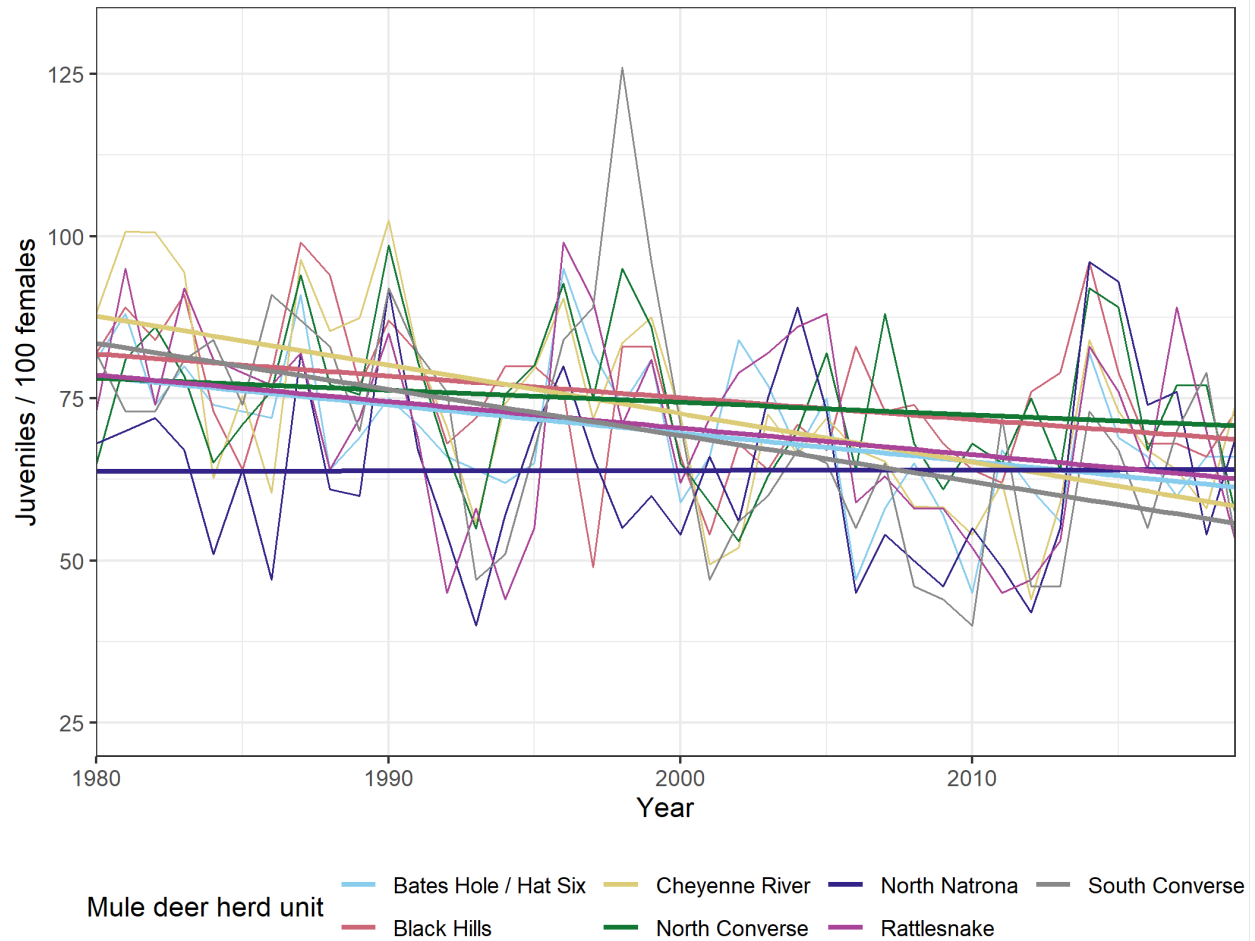


Fig. 50. Mule deer age ratios (proportion of juveniles/100 adult females) by mule deer herd unit in Casper Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Changes in landscape variables

Trends by herd unit

In the Casper region, agriculture, drought, and oil and gas wells had large changes in some herd units (Table 6).

Table 6. Trends from linear regression for landscape variables in mule deer herd units from 1980-2019 in Wyoming, USA. Values represent relative effects and are scaled so variables can be directly compared. Bolded values represent trends that are statistically significant ($p \leq 0.05$). Significant trends are also summarized as: *increase* + (>0), *large increase* ++ (≥ 0.01), *decrease* - (≥ -0.01), or *large decrease* -- (≤ -0.01). Ag = agriculture.

	Bates Hole / Hat Six	Black Hills	Cheyenne River	North Converse	North Natrona	Rattlesnake	South Converse
Ag	-0.004 -	-0.021 --	-0.011 -	-0.008 -	-0.010 -	-0.011 --	-0.042 --
Drought	0.087	0.059	0.270 ++	0.143	0.105	0.117	0.106
Oil/gas wells	-0.008 -	-0.001 -	-0.001	0.007 +	-0.014 --	0.0002	-0.002 -
Shrubland	-0.007	0.001	-0.062 --	-0.089 --	-0.055	-0.017	-0.035
Summer precipitation	0.111	2.14	2	1.56	0.495	0.279	0.553
Wind	NA	NA	NA	0.003 +	NA	NA	0.0004 +
Winter temperatures	0.013	0.008	0.006	0.005	0.014	0.016	0.004

Land use

Although land use proportion was relatively stable over time, the amount of shrubland and agriculture varied across herd units. Shrubland includes bitterbrush shrub steppe, desert shrub, greasewood fans and flats, mesic upland shrub, saltbush fans and flats, and xeric upland shrub. Agriculture is defined as cropland, hay land, and food production excluding rangeland.

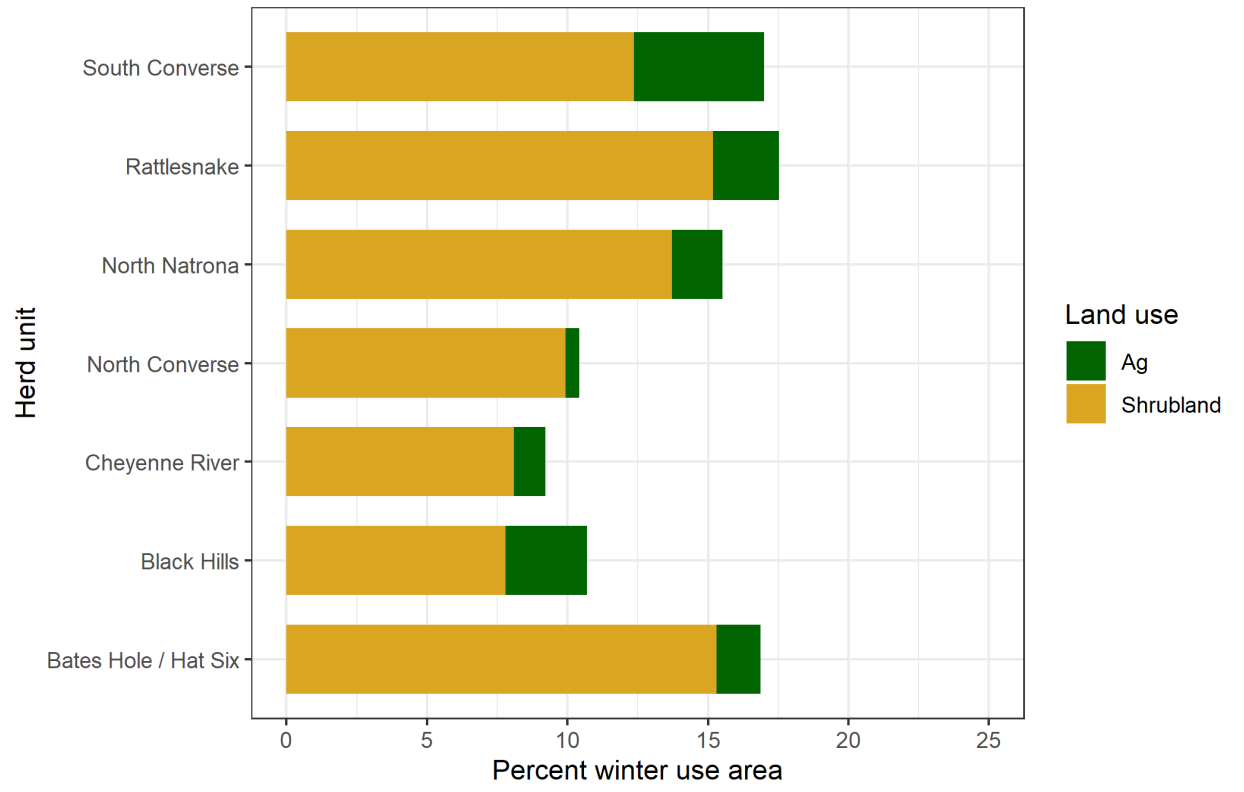


Fig. 51. Mean proportion of agriculture and shrubland in winter-use areas for 1985-2019 by herd unit in Casper Wyoming Game and Fish Department region, Wyoming, USA.

Average winter temperature (December-March of previous year)

Mean winter temperatures across herd units varied over time. The mean temperature of winter-use areas differed only slightly by herd units in this region, but patterns tracked closely between herd units.

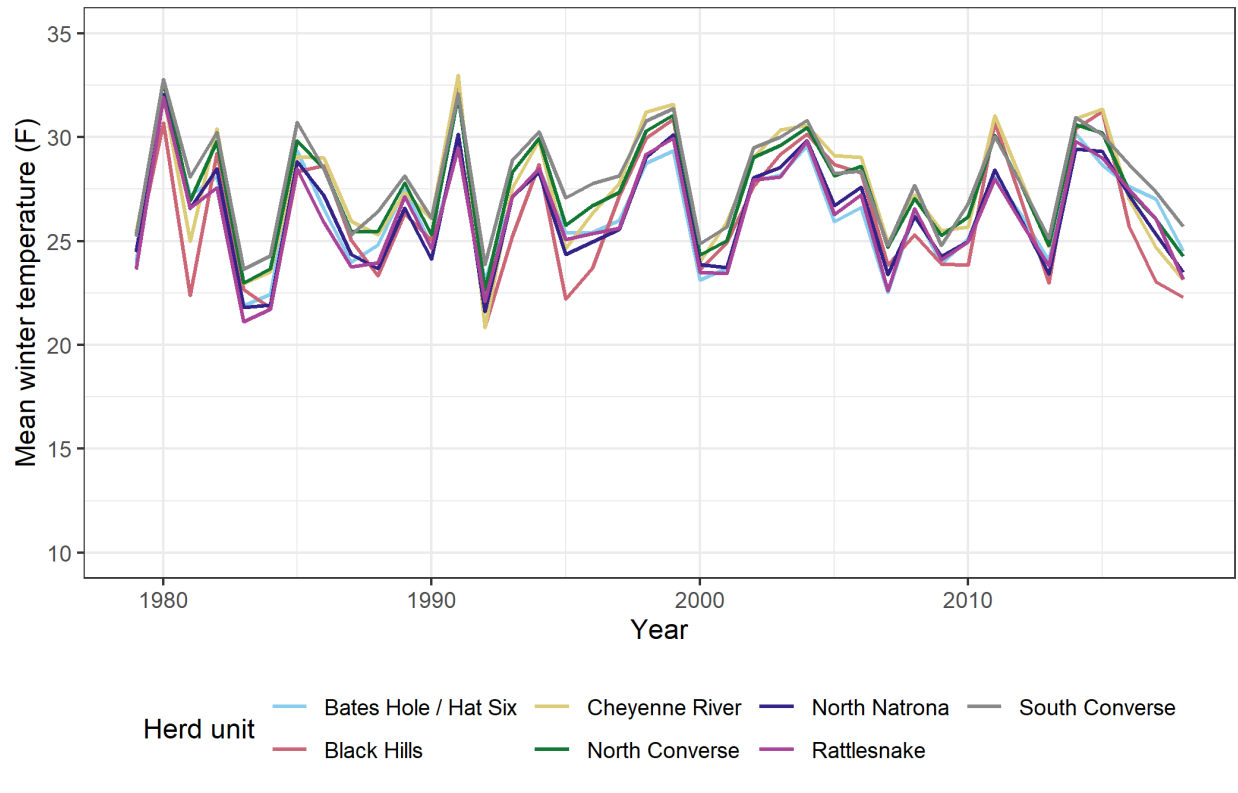


Fig. 52. Mean temperature (°F) in winter-use areas of mule deer herd units in Casper Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Summer precipitation (May-August of the previous year)

Precipitation during May-August of the year before counts varied over time. The winter-use area in Black Hills herd unit had consistently more precipitation than other herd units, although fluctuations in summer rainfall generally tracked between herd units in the region.

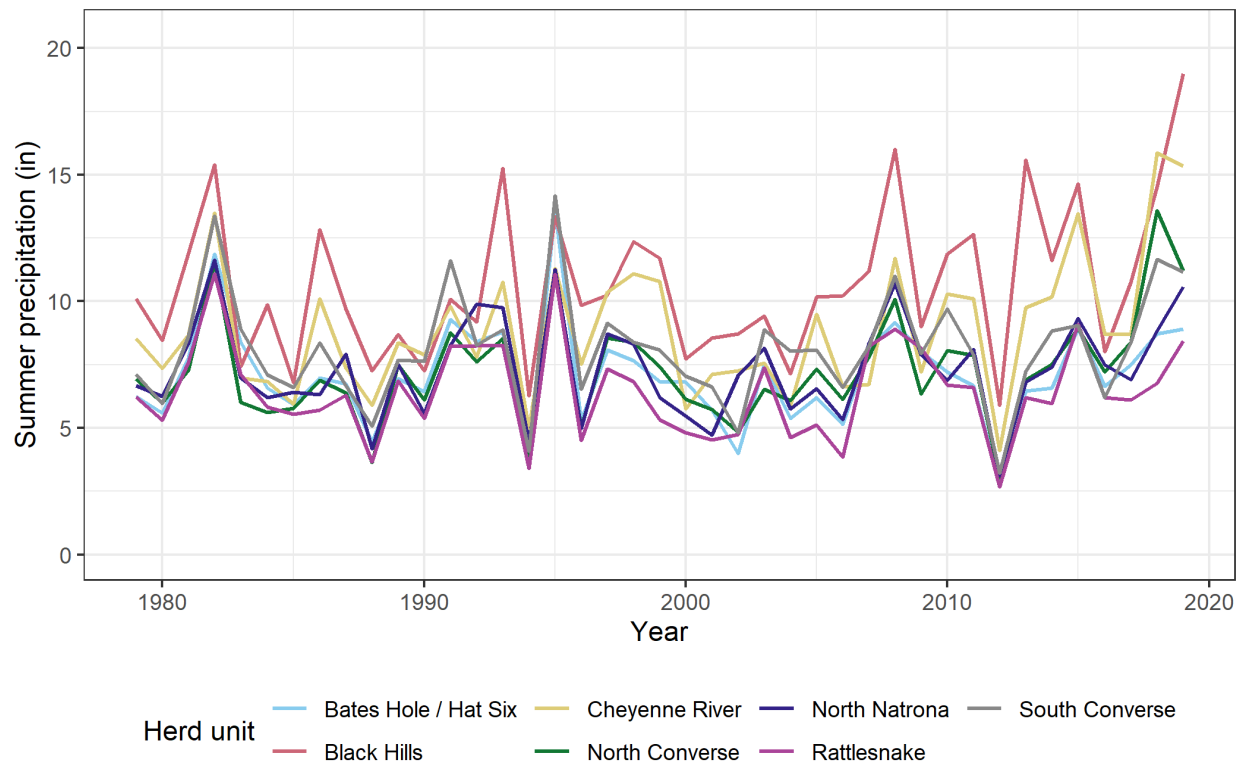


Fig. 53. Mean precipitation (inches) during the previous May-August in winter-use areas of mule deer herd units in Casper Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Cumulative drought

Cumulative drought (the number of months with severe drought) across herd units varied over time but patterns of drought occurrence were similar between herd units. All herd units in the region experienced drought during 1988-1993 and 2013-2017. Herd units experienced variable timing and severity of drought during 2001-2011. During this time, Cheyenne River herd unit had more months of cumulative drought that peaked during the late 2000s compared with other herd units in the region.

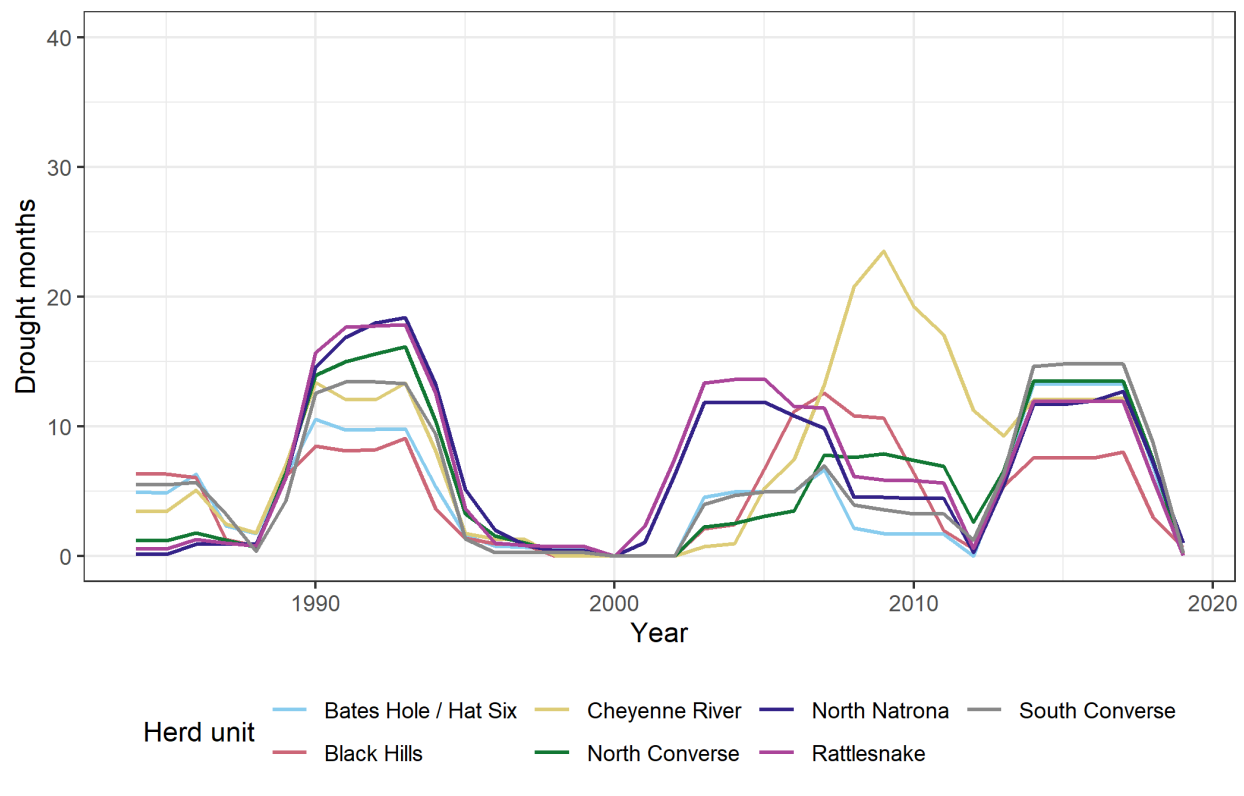


Fig. 54. Cumulative drought (months of severe drought during the previous 5 years) in mule deer winter-use areas within mule deer herd units in Casper Wyoming Game and Fish Department region, 1985-2019, Wyoming, USA.

Changes in oil/gas density

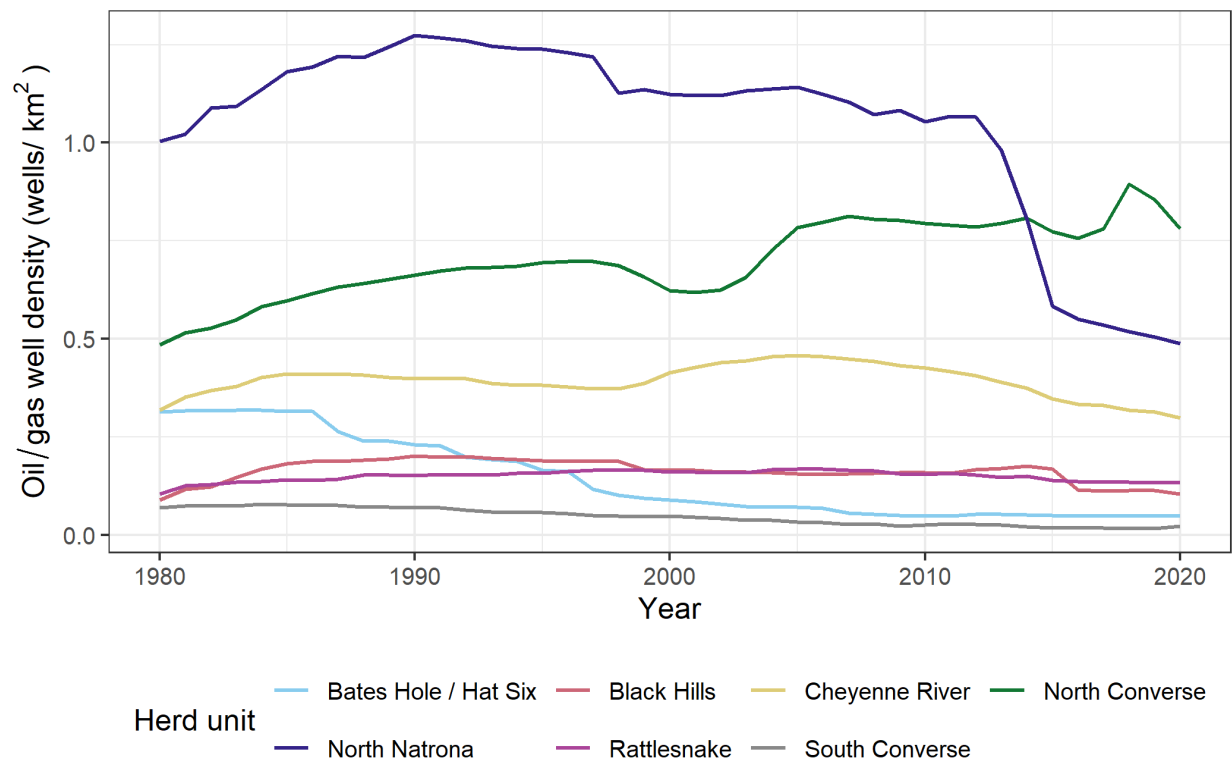


Fig. 55. Operational oil/gas well density (wells/km²) over time by mule deer herd unit, Wyoming, USA.

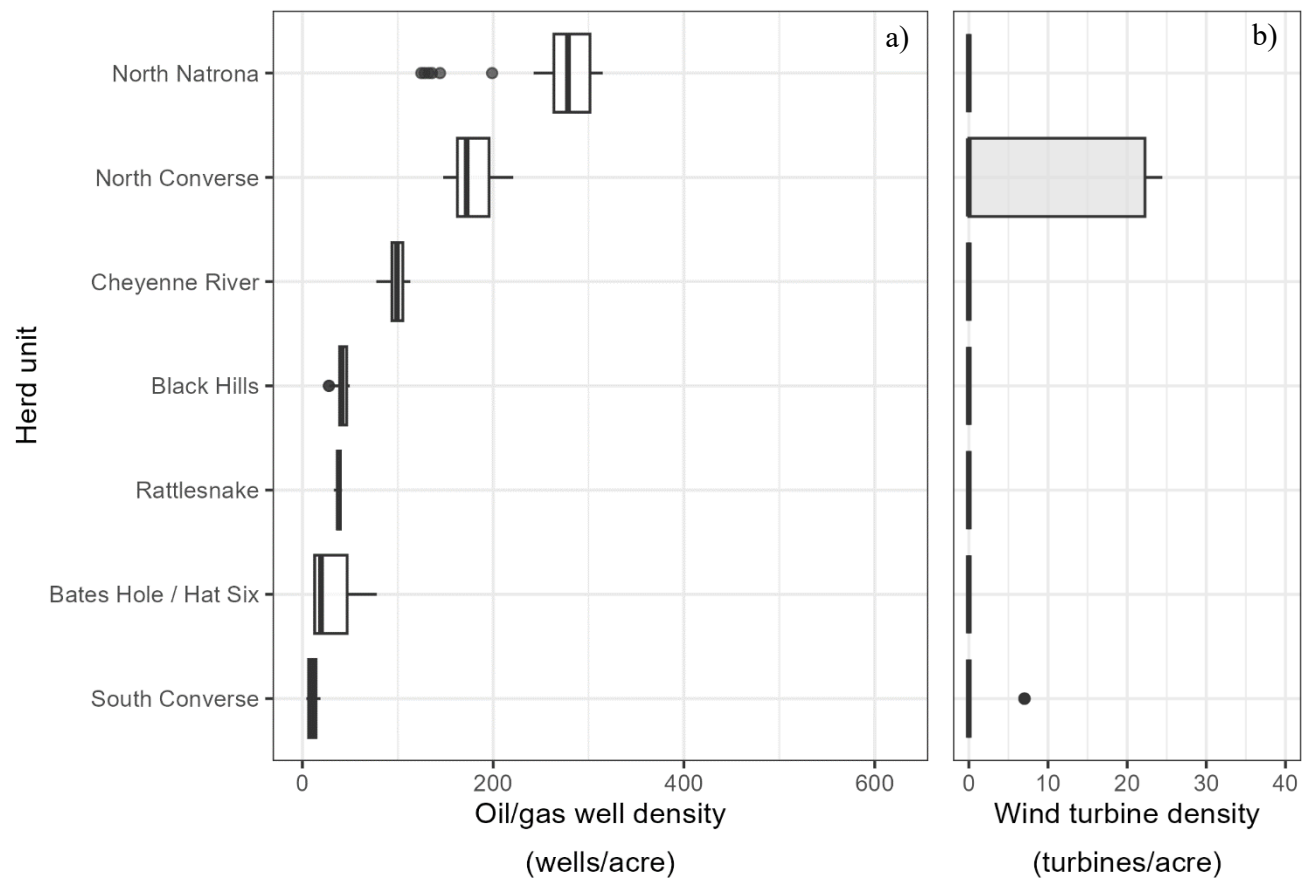


Fig. 56. Spatial variability in density of (a) oil/gas wells and (b) wind turbines in mule deer winter-use areas in Casper Wyoming Game and Fish Department (WGFD) region, 1985-2019, Wyoming, USA. Boxplots are on different scales and both show first quartile, median, and third quartile of data, with whiskers extending to the largest value within $1.5 * \text{IQR}$ (interquartile range) and outliers plotted as individual points.

Laramie region

Winter-use areas

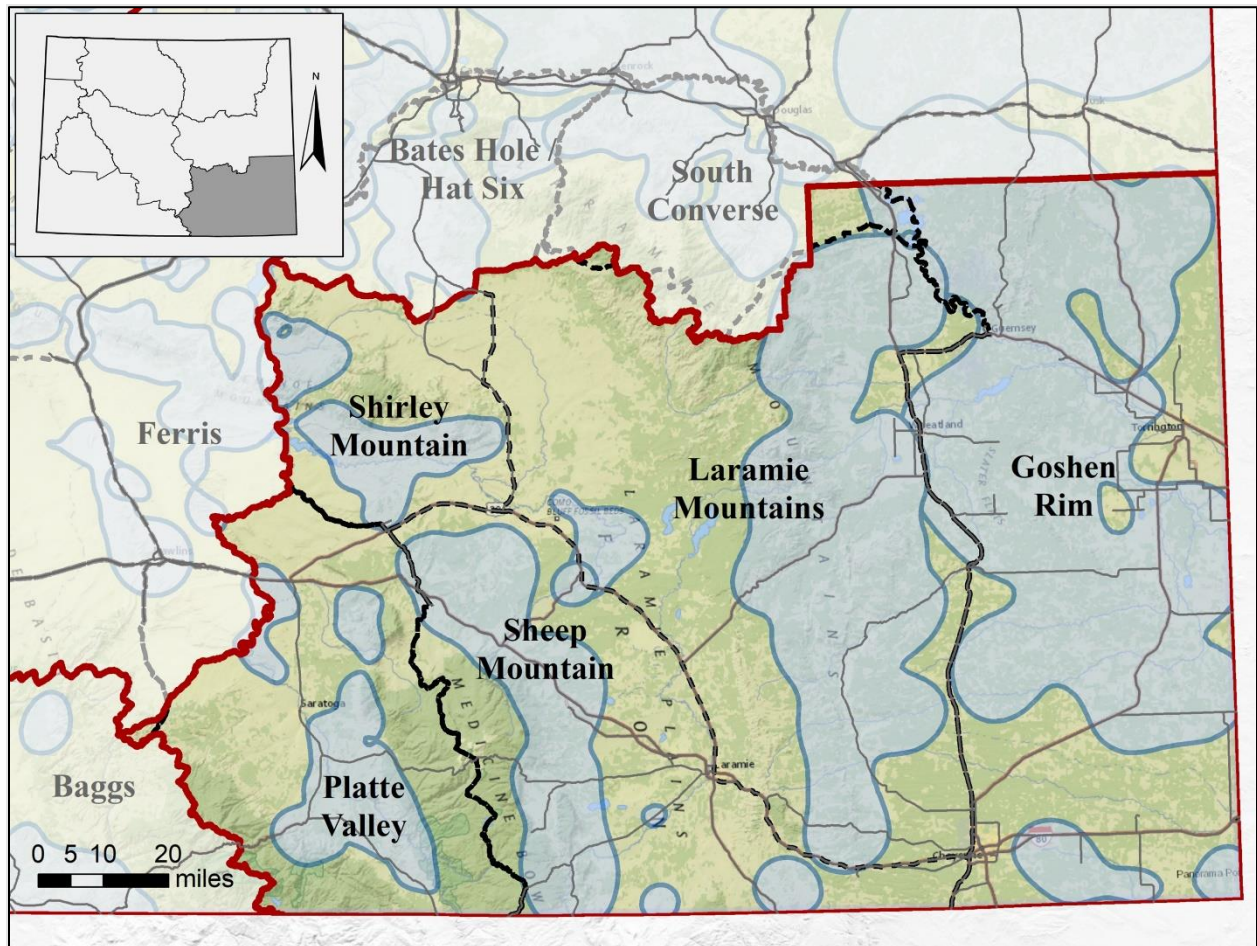


Fig. 57. Mule deer herd units delineated by dashed black lines (bold text), regions delineated by solid red lines, and winter-use areas (blue polygons) within Laramie region of Wyoming Game and Fish Department (WGFD, State of Wyoming 2020). Roads shown as grey lines. Inset map shows region location in relation to the state. National Geographic World Map basemap credit: Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Recruitment

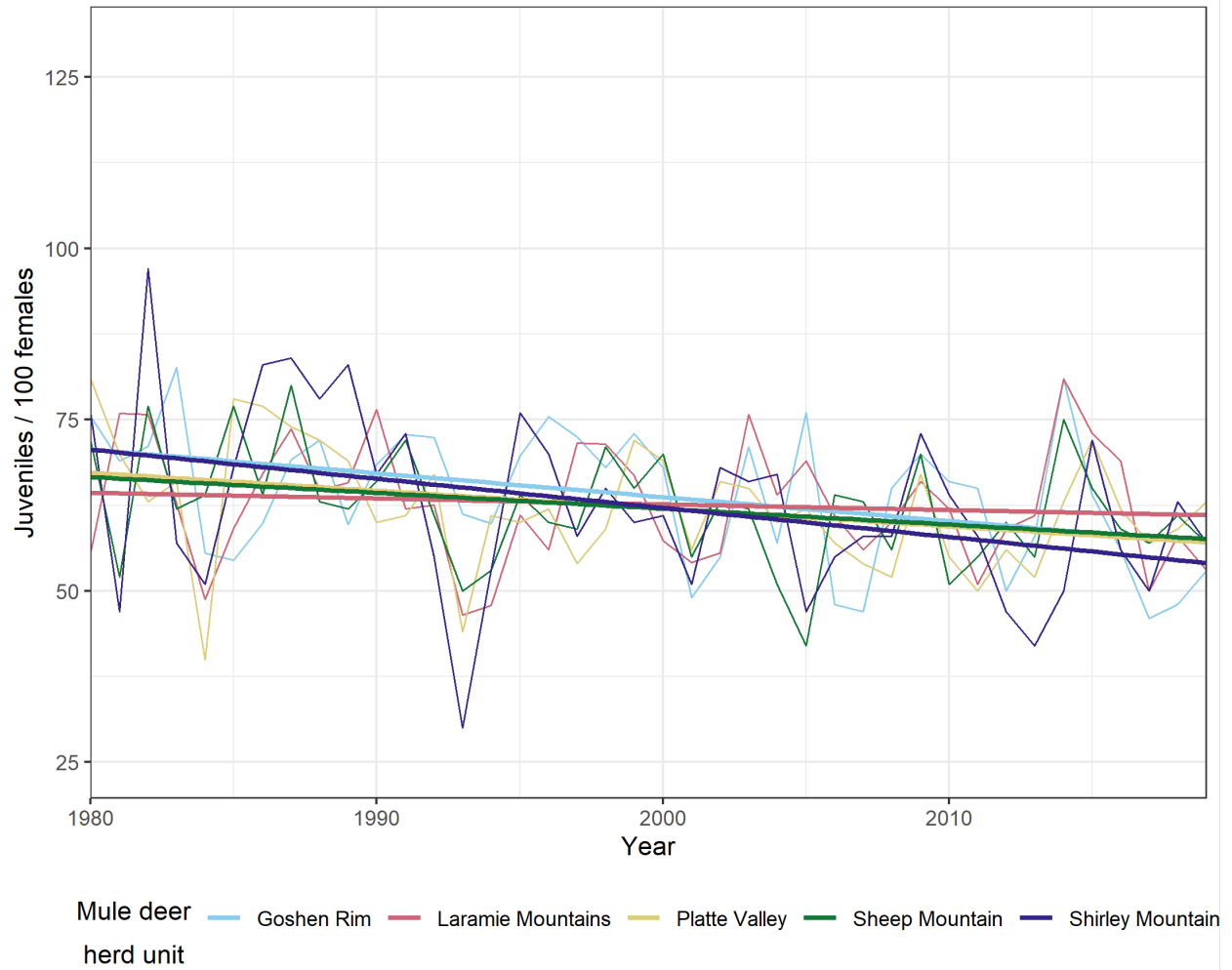


Fig. 58. Mule deer age ratios (proportion of juveniles/100 adult females) by mule deer herd unit in Laramie Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Changes in landscape variables

Trends by herd unit

In the Laramie region, agriculture, drought, and shrubland had large changes in some herd units (Table 7).

Table 7. Trends from linear regression for landscape variables in mule deer herd units from 1980-2019 in Wyoming, USA. Values represent relative effects and are scaled so variables can be directly compared. Bolded values represent trends that are statistically significant ($p \leq 0.05$). Significant trends are also summarized as: *increase* + (>0), *large increase* ++ (≥ 0.01), *decrease* - (≥ -0.01), or *large decrease* -- (≤ -0.01). Ag = agriculture.

	Goshen Rim	Laramie Mountains	Platte Valley	Sheep Mountain	Shirley Mountain
Ag	-0.054 --	-0.003	-0.006 -	0.009 +	-0.005 -
Drought	0.355 ++	0.314 ++	0.244 ++	0.246 ++	0.257 ++
Oil/gas wells	0.001 +	-0.00006 -	-0.0003 -	-0.0005 -	-0.0001 -
Shrubland	-0.127 --	-0.030	0.067 ++	0.004	0.047
Summer precipitation	1.180	0.0538	-0.589	-0.020	-0.512
Wind	NA	0.0005 +	NA	0.003 +	0.003 +
Winter temperatures	-0.001	0.0185	0.031	0.025	0.014

Land use

Although land use proportion was relatively stable over time, the amount of shrubland and agriculture varied across herd units. Shrubland includes bitterbrush shrub steppe, desert shrub, greasewood fans and flats, mesic upland shrub, saltbush fans and flats, and xeric upland shrub. Agriculture is defined as cropland, hay land, and food production excluding rangeland.

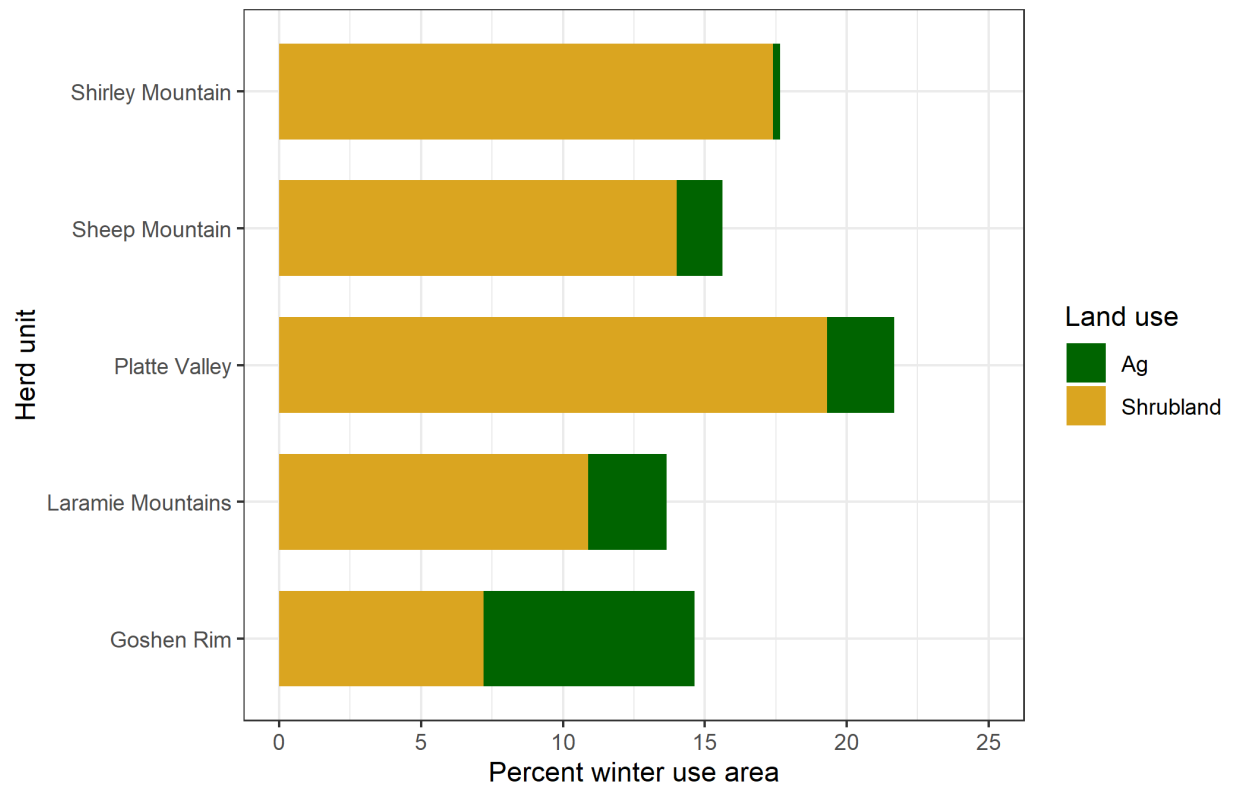


Fig. 59. Mean proportion of agriculture and shrubland in winter-use areas for 1985-2019 by herd unit in Laramie Wyoming Game and Fish Department region, Wyoming, USA.

Average winter temperature (December-March of previous year)

Mean winter temperatures across herd units varied over time. The mean temperature differed by herd units, but patterns tracked closely between herd units.

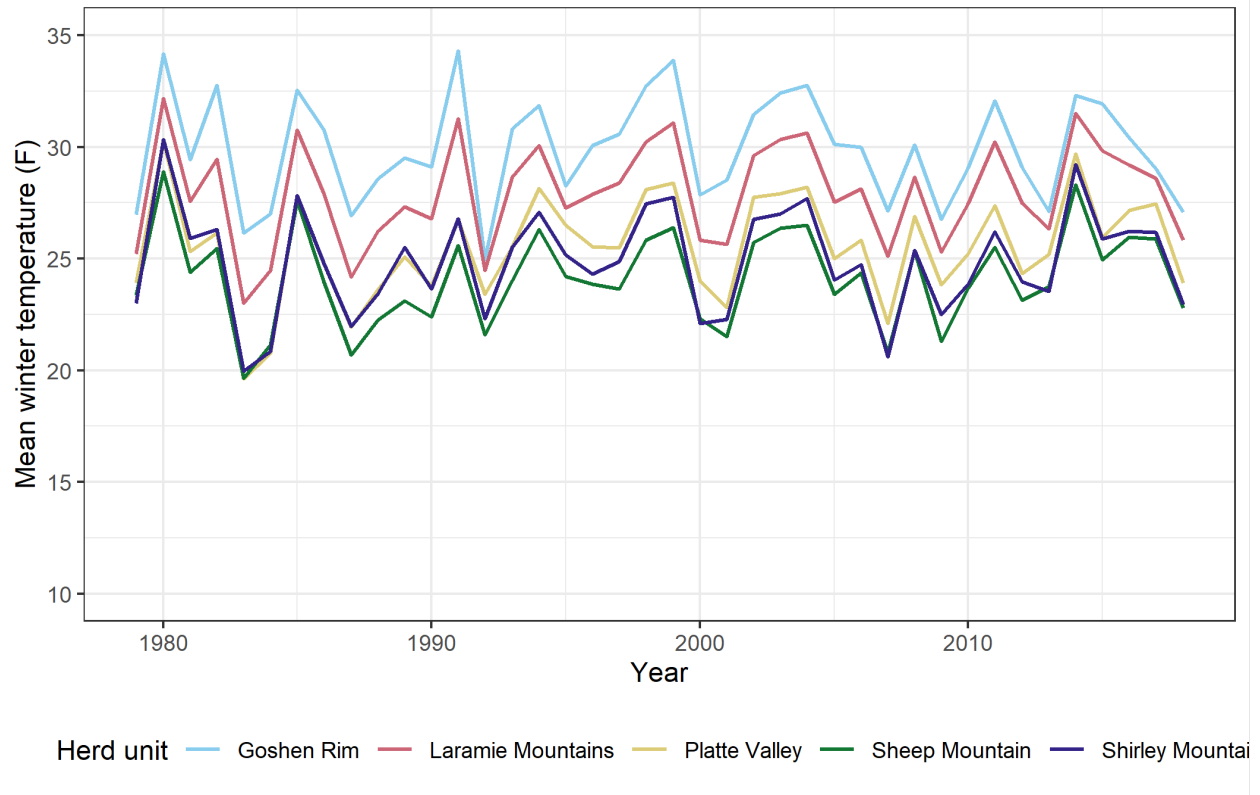


Fig. 60. Mean temperature (°F) in winter-use areas of mule deer herd units in Laramie Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Summer precipitation (May-August of the previous year)

Precipitation during May-August of the year before counts across herd units varied over time, but fluctuations in summer precipitation were similar between herd units.

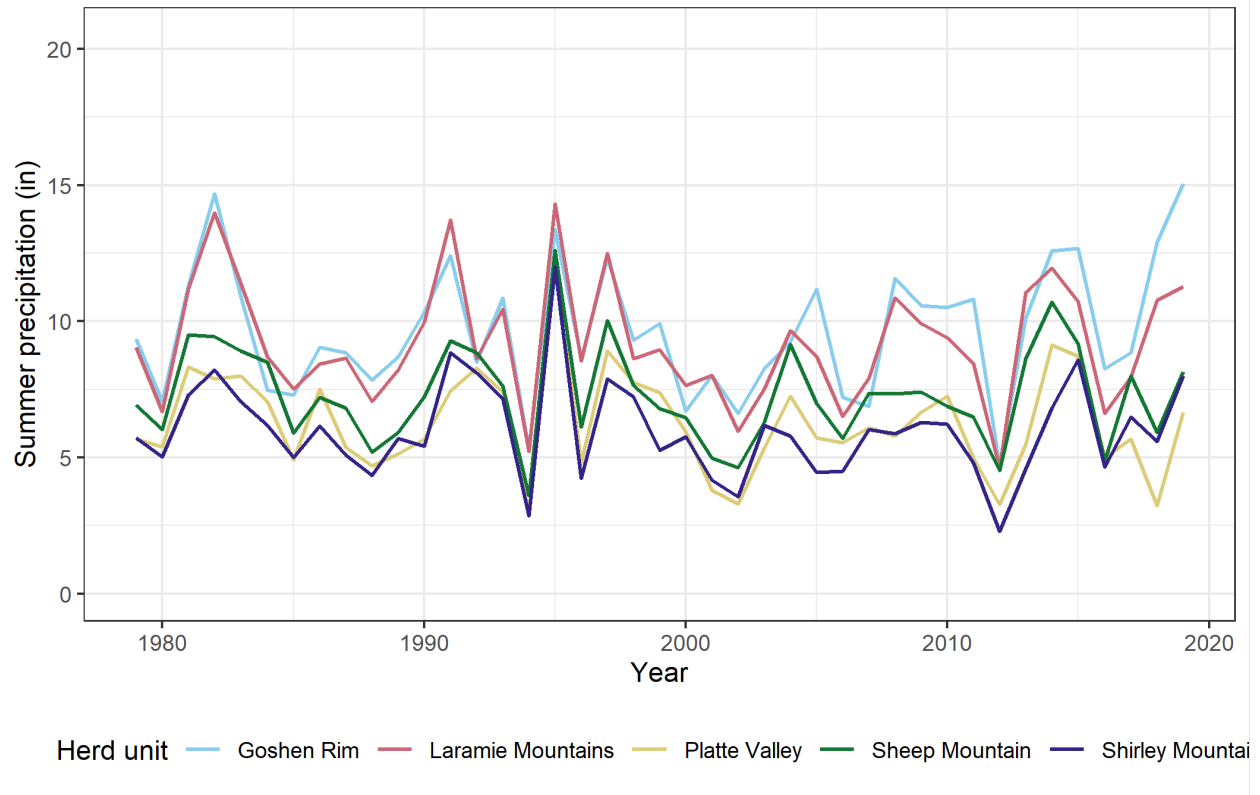


Fig. 61. Mean precipitation (inches) during the previous May-August in winter-use areas of mule deer herd units in Laramie Wyoming Game and Fish Department region, 1980–2019, Wyoming, USA.

Cumulative drought

Cumulative drought (the number of months with severe drought) across herd units varied over time but patterns of drought occurrence were similar between herd units. All herd units in the region experienced several months of drought units during the early 1990s, 2002-2007, and 2013-2017. Goshen Rim and Laramie Mountains herd unit had more months of cumulative drought between 2002-2017 than other herds in the region.

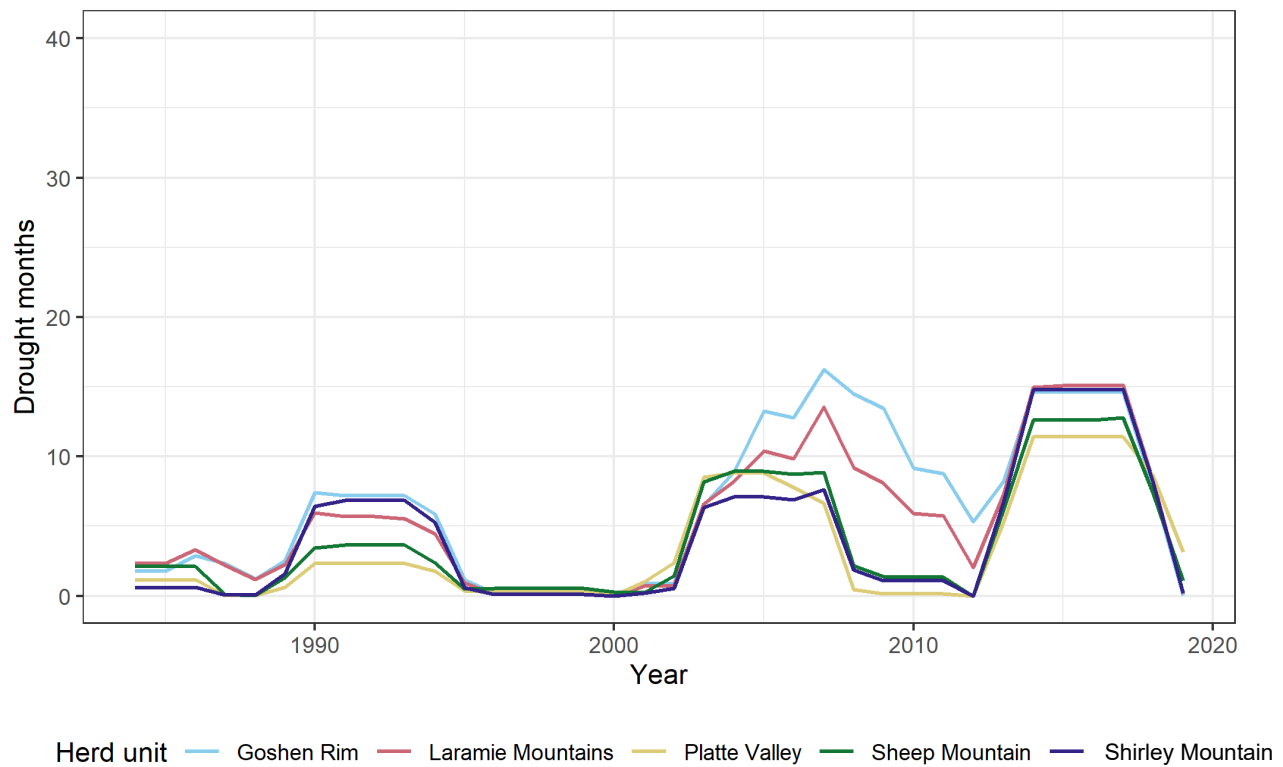


Fig. 62. Cumulative drought (months of severe drought during the previous 5 years) in mule deer winter-use areas within mule deer herd units in Laramie Wyoming Game and Fish Department region, 1985-2019, Wyoming, USA.

Changes in oil/gas density

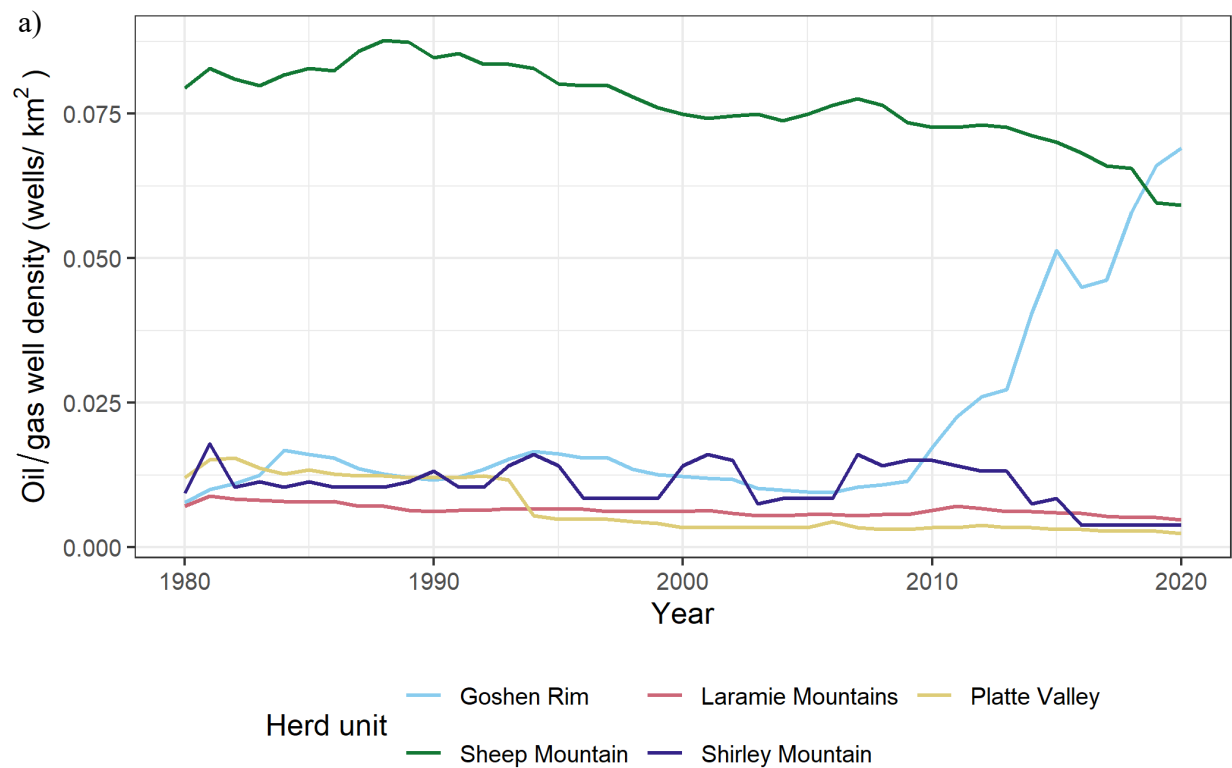


Fig. 63. Operational oil/gas well density (wells/km²) over time by mule deer herd unit in Wyoming, USA.

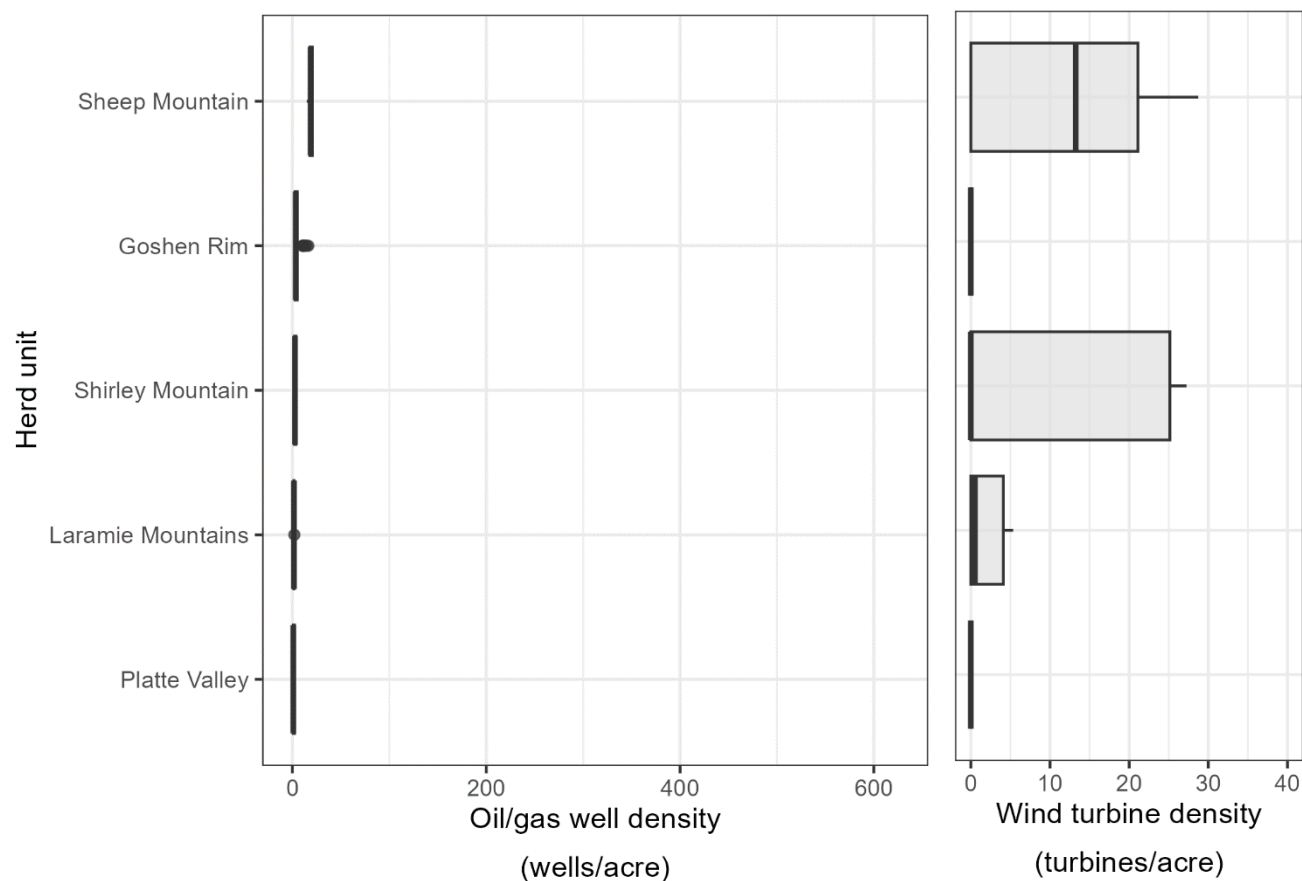


Fig. 64. Spatial variability in density of (a) oil/gas wells and (b) wind turbines in mule deer winter-use areas in Laramie Wyoming Game and Fish Department region, 1985-2019, Wyoming, USA. Boxplots are on different scales and both show first quartile, median, and third quartile of data, with whiskers extending to the largest value within 1.5 * IQR (interquartile range) and outliers plotted as individual points.

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Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Appendix

Table S1. Habitat treatment types in Wyoming USA using U.S. Geological Survey (USGS)-defined categories compared with categories in 4 different treatment libraries: Density Disturbance Calculation Tool (DDCT), Land Treatment Digital Library (LTDL), Wyoming Game and Fish Department (WGFD), Bureau of Land Management (BLM). Categories, descriptions, and information included are not consistent between agencies.

Data source & coverage	Treatment type (USGS defined)	Number of treatments	Categories of treatment types (defined by data source)			
			<i>LTDL Treatment Type</i> ("Trt_Type_Major")	<i>LTDL Treatment Subtype</i> ("Trt_Type_Sub")	<i>LTDL Specific Treatment</i> ("Treatment_Type")	<i>LTDL Purpose</i> ("Purpose")
LTDL: Land Treatment Digital Library (USGS) - BLM land, western U.S.					Herbicide Application (44), Herbicide Application: Brush/Tree Control (36), Noxious Weeds: Weed Control - Herbicide Application (42)	
	<i>Chemical Treatment</i>	129	Herbicide, Weeds, Chemical	Herbicide (122), Chemical (1), Weeds (6)		
	<i>Habitat Improvement</i>	72	Biological Control, Closure/Exclosure, Seeding, Soil Stabilization	Grazing (2), Closure (1), Exclosure (1), Drill Seeding (14), Seeding (2), Aerial Seeding (11), Ground Seeding (24), Seedling Planting (15), Soil Stabilization (2)		Habitat I/improvement (294 - 164 Rx burn)
	<i>Mechanical Treatment</i>	248	Vegetation/Soil Manipulation	Vegetation Disturbance (173), Soil Disturbance (11), Slash Treatment (17), Timber (47)	General Treatment: Vegetation Removal (1),	
	<i>Prescribed Burn</i>	420	Prescribed Burn	Prescribed Burn (420)		

	<i>Unknown Veg. Treatment</i>	17	Other	Other Treatment (12), General Treatment (5)	
Data source & coverage	Treatment type (USGS defined)	Number of treatments	Categories of treatment types (defined by data source)		
DDCT: Density-Disturbance-Calculation-Tool (WyGISC OneSteppe, compilation of agencies) - Wyoming			<i>DDCT Treatment Type</i> ("TrtDescription")	<i>DDCT Additional Information</i> ("Comments")	
	<i>Chemical Treatment</i>	548	Chemical Treatment		
	<i>Habitat Improvement</i>	186	Habitat Improvement		
	<i>Mechanical Treatment</i>	660	Mechanical Treatment		
	<i>Prescribed Burn</i>	559	Prescribed Burn		
	<i>Unknown Veg. Treatment</i>	794	Unknown Veg. Treatment		
BLM VTRT (Vegetation Treatment Areas) - BLM land			<i>VTRT Treatment Type</i> ("TRTMNT_TYP")	<i>VTRT Treatment Subtype</i> ("TRTMNT_SUB")	<i>VTRT Additional Information</i> ("TRTMNT_COM")
	<i>Unknown Vegetation Treatment</i>	3	Biological (#1)	Classical (3)	
	<i>Chemical Treatment</i>	163	Chemical (#2)	Pesticide (163)	
	<i>Prescribed Burn</i>	287	Prescribed fire (#3)	None (287)	
	<i>Mechanical Treatment</i>	641	Physical (#4)	Plant (13), Remove (605), Other (23)	

Data source & coverage	Treatment type (USGS defined)	Number of treatments	Categories of treatment types (defined by data source)			
			<i>VMAP Treatment Type</i> ("TRT_TYPE_N")	<i>VMAP Specific Treatment</i> ("TRT_ACTVTY")	<i>VMAP Purpose</i> ("TRT_DRIVER")	<i>VMAP Treatment Subtype</i> ("TRT_SUBTYP")
BLM VMAP (Vegetation Management Action Portal) - BLM land	<i>Chemical Treatment</i>	13786	Chemical	Cutting Stump/Spraying Surface (10), Spraying (13423), Wiping (1), NA (352)	Invasive Species Removal	Pesticide
	<i>Habitat Improvement</i>	29	Revegetation	Broadcasting (7), Planting (2), NA (20)		
	<i>Mechanical Treatment</i>	40	Physical	Digging (15), Hand Pulling (7), Hoeing (2), Lop and Scattering (8), Masticating (4), Plowing (1), Protective Mulching (3), Thinning (1), NA (3)		
	<i>Unknown Vegetation Treatment</i>	24	Biological Control	Releasing (21), Targeted Grazing (1), NA (2)		

Data source & coverage	Treatment type (USGS defined)	Number of treatments	Categories of treatment types (defined by data source)
WGFD Completed Treatments: WGFD - Wyoming			WGFD Treatment Type ("Treat_Type")
	<i>Prescribed Burn</i>	190	RX (35), RX-Cut/Pile (78), RX-Slash (74), RX + Planting (3)
	<i>Chemical Treatment</i>	81	Herbicide (3), Spike (36), Spray (40), Mowing + Spray (2)
	<i>Habitat Improvement</i>	31	Exclosure (1), Fertilizer (2), Planting (14), Pitting (5), Reveg plot (1), Seeding (7), Willow Planting (1)
			Aerator (9), Aerator - Mosaic (3), Aerator 30% + seed (1), Aerator 50% + seed (15), Aerator 60-80% (2), Aerator 80% (10), Aspen Cut (12), Aspen Cut 30% (1), Aspen Ripping (20), Beating-UNK (1), Chaining (2), Control (5), Dixie Harrow (4), Harrow (1), Harrow + seeding (2), Masticate (8), Mowing (161), Mowing + seed (1), Mowing + Shrub Planting (1), Mowing 30% (72), Mowing 50% (25), Mowing 80% (1), MX (27), MX-Clear cut (1), MX-Conifer 30% Aspen Cut (2), MX-Conifer Removal (17), MX-Conifer Removal 25% Aspen cut (3), MX-Conifer Removal 30% Aspen Cut (2), MX-Conifer Removal 50% Aspen cut (2), MX-Conifers (63), Ripping (23), Slash (8), Thinning (23)
	<i>Mechanical Treatment</i>	528	
	<i>Unknown Veg. Treatment</i>	7	Unk (2), UNK (5)
			WGFD Additional Information ("Comments")